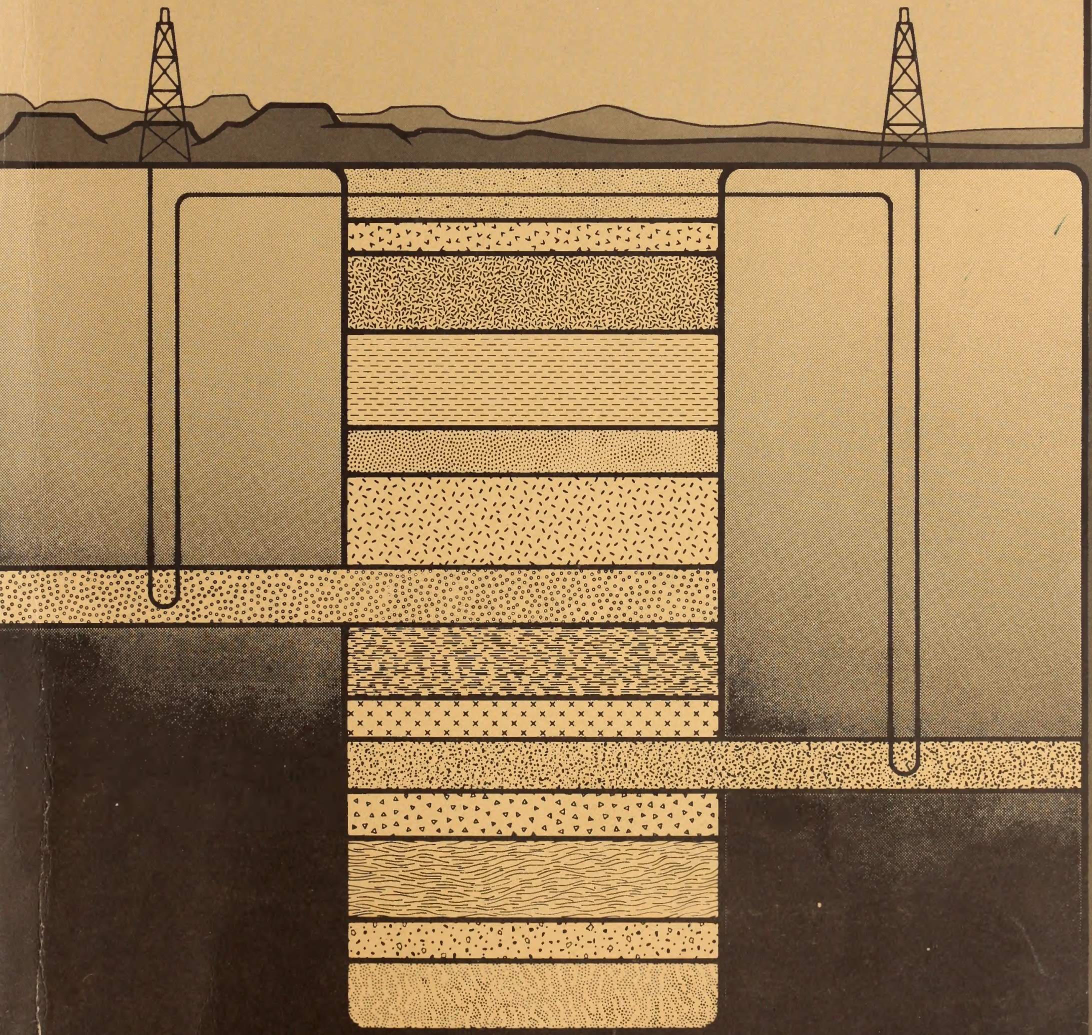
Draft

Environmental Statement
CO_2 Project

Wasson Field/Denver Unit



Department of the Interior/Bureau of Land Management

IN REPLY REFER TO

United States Department of the Interior

BUREAU OF LAND MANAGEMENT
NEW MEXICO STATE OFFICE
P.O. BOX 1449
SANTA FE, NEW MEXICO 87501

NOTICE

Enclosed is the Draft Environmental Statement (DES) for Shell Oil Company's proposed CO_2 project. Your review and comments on the adequacy of the DES are invited. Please direct your comments to the State Director (911) at the address on this letterhead. The comment period will end August 27, 1979.

Public hearings will be held on the following schedule:

Monday, August 13, Roswell Inn, Roswell, NM
Tuesday, August 14, Holiday Inn Midtown, Albuquerque, NM
Thursday, August 16, Empire Electric Bldg., Cortez, CO

The hearings will commence at 1:00 p.m. and 7:00 p.m. at each location. Written requests to testify should be submitted prior to close of business on August 8, 1979. The form on the back of this sheet is for this purpose.

Pursuant to the November 29, 1978 regulations of the Council on Environmental Quality BLM may choose not to reprint the DES text in full. If no major changes are necessary, the DES text will be summarized and included in a separate volume with the comments and responses. The DES and the separate volume together would constitute the final environmental statement. Please keep this DES so that it can be included with the final statement in the event the DES text is not fully reprinted.

Written comments received by August 27, 1979 and testimony presented at the public hearing will be fully considered and evaluated in preparation of the FES. Those comments that pertain to the adequacy of the draft assessment or present new data will be included in the FES.

Billy M Brady
Arthur W. Zimmerman for
State Director

PUBLIC HEARING REGISTRATION FORM

For Public Hearings on the adequacy of BLM's draft EIS for the Shell Oil Company's proposed CO_2 project.

(Please Print)

TO: State Director, Bureau of Land Management, New Mexico State Office, P.O. Box 1449, Santa Fe, New Mexico 87501

FROM: NAME ______________________________

Street Address ______________________________

City-State ____________________ Zip Code __________

Representing ______________________________

I wish to appear at the following public hearing session and express my views:

Check time ________ 1:00 p.m. Check location _____ Albuquerque, NM

________ 7:00 p.m. _____ Roswell, NM

_____ Cortez, CO

I intend to submit written documentation: Yes ___ No ___

Signature ______________________________ __________

Verbal testimony limited to 10 minutes; written testimony acceptable until August 27, 1979.

DEPARTMENT OF THE INTERIOR

DRAFT

ENVIRONMENTAL STATEMENT

ON THE

CO_2 PROJECT

WASSON FIELD/DENVER UNIT

PREPARED BY

BUREAU OF LAND MANAGEMENT

DEPARTMENT OF THE INTERIOR

STATE DIRECTOR, NEW MEXICO STATE OFFICE

SUMMARY

Draft (x) Final ( ) Environmental Statement

Department of the Interior, Bureau of Land Management

1. Type of Action: Administrative (x) Legislative ( )

2. Brief Description of Action: The proposed action is based on an application for rights-of-way for a pipeline and related facilities to transport CO_2 from southwest Colorado through New Mexico to the Wasson Oil Field near Denver City, Texas and associated drilling authorizations within the CO_2 well field. Components of the proposed action are: a CO_2 well field in southwest Colorado consisting of 140 wells and 13 central facilities with the necessary access roads and connecting pipelines; a main pipeline 478 miles long; injection facilities in the oil field; a microwave communication system of 14 towers; and electric transmission lines to provide necessary power requirements.

3. Summary of Environmental Impacts

a. Temporary disturbance of 6551 acres of which 397 would be permanently disturbed.
b. Removal of 400 million standard cubic feet of CO_2 per day from the reservoir. Some of the CO_2 would be recovered at the oil field.
c. There would be local increases in fugitive dust and road traffic during construction.
d. There would be some opportunity for short term jobs for unskilled labor.
e. There would be an increase in the tax base.
f. As much as 280 million additional barrels of oil would be recovered by the proposed action.
g. The visual aspects of the area would be impacted by the construction of wells, access roads, pipelines, and other proposed facilities.
h. The cultural resources would be avoided whenever possible. There may be some loss of cultural resources which have no surface manifestations.

4. Alternatives Considered: The alternatives considered are a no-action alternative and variations in the routes of the main pipeline, CO_2 gathering lines, and transmission lines. There are no alternative locations for the CO_2 well field and each well site would be analyzed individually.

5. Comments on the Draft Environmental Statement Have Been Requested From Various Agencies and Interest Groups: See attached list.

6. Date Draft Statement was made available to EPA and the Public: JUL 13 1979

Attachment to No. 5: Comments will be requested from the following:

FEDERAL

Advisory Council on Historic Preservation

Department of Agriculture
- Soil Conservation Service
- U. S. Forest Service

Department of Commerce

Department of Defense
- Corps of Engineers

Department of Energy

Department of Health, Education & Welfare

Department of Housing and Urban Development

Department of the Interior
- Bureau of Indian Affairs
- Bureau of Mines
- Bureau of Reclamation
- Fish and Wildlife Service
- Heritage Conservation and Recreation Service
- National Park Service
- U. S. Geological Survey

Department of Labor
- Occupational Safety and Health Administration

Department of Transportation

Environmental Protection Agency

Interstate Commerce Commission

STATE

The State Clearing Houses for Colorado, New Mexico and Texas will coordinate comments from all interested state agencies in their respective states.

LOCAL

Colorado

Dolores County Commissioners
Montezuma County Commissioners
La Plata County Commissioners
Montelores Planning Commission

New Mexico

Bernalillo County Commissioners
Chaves County Commissioners
Guadalupe County Commissioners
Lea County Commissioners
Lincoln County Commissioners
McKinley County Commissioners
Sandoval County Commissioners
San Juan County Commissioners
Santa Fe County Commissioners
Torrance County Commissioners
San Juan Regional Planning Commission
Southeastern Economic Development District
Southern Rio Grande Council of Governments

Texas

Gaines County Commissioners Court
Yoakum County Commissioners Court
South Plains Association of Governments
Permian Basin Association of Governments

NON-GOVERNMENTAL ORGANIZATIONS

Central New Mexico Audubon Society
Colorado Association of Commerce and Industry
Colorado Four Wheel Drive Clubs, Incorporated
Colorado Open Space Council (COSC) Mining Workshop
Colorado Open Space Council
Colorado Parks and Recreation Society
Colorado Petroleum Association
Colorado River Water Conservation District
Colorado Ute Electric Association
Colorado Wildlife Association
Conservation Foundation
Defenders of Wildlife
Ecological Society
Environmental Action of Colorado
Environmental Affairs Committee, Colorado Bar Association
Environmental Defense Fund

NON-GOVERNMENTAL ORGANIZATIONS (Contd.)

- Friends of the Earth
- Izaak Walton League of America
- National Council of Public Land Users
- National Energy Law and Policy Institute
- National Wildlife Federation
- Natural Resources Defense Council
- New Mexico Cattle Growers' Association
- New Mexico Citizens for Clean Air and Water
- New Mexico Conservation Coordination Council
- The New Mexico Natural History Institute
- New Mexico Wildlife Federation
- School of American Research
- Sierra Club
- Soil Conservation Society of America
- Trout Unlimited
- Wilderness Society
- Wildlife Management Institute
- Wildlife Society

TRIBAL

- Office of the Navajo Tribal Chairman
- Southern Ute
- Ute Mountain Ute
- Northern Pueblo Agency
- Santa Ana
- Zia
- San Felipe
- Jemez

Where Copies May Be Inspected

Copies of the draft environmental statements will be available for public inspection at the locations listed below.

BUREAU OF LAND MANAGEMENT

Albuquerque District Office
3550 Pan American Freeway, N.E.
Albuquerque, New Mexico 87107

Farmington Resource Area Office
900 La Plata Highway
P.O. Box 568
Farmington, New Mexico 87401

Roswell District Office
1717 W. Second Street
Featherstone Farm's Building
P. O. Box 1397
Roswell, New Mexico 88201

New Mexico State Office
U.S. Post Office Building, South Federal Place
P.O. Box 1449
Santa Fe, New Mexico 87501
(will provide copies on request as long as supplies last)

Durango Resource Area Office
701 Camino del Rio
Durango, Colorado 81301

Montrose District Office
Highway 550 South
Montrose, Colorado 82901

Colorado State Office
Colorado State Bank, 7th Floor
1600 Broadway
Denver, Colorado 80202

Denver Service Center Library
BLDG 50, Denver Federal Center
Denver, Colorado 80225

Washington Office of Public Affairs
18th and C Street
Washington, D.C. 20240

Public Libraries

Albuquerque City Library
501 Copper Avenue N.W.
Albuquerque, New Mexico 87107

Farmington City Library
302 North Orchard Avenue
Farmington, New Mexico 87401

Roswell Public Library
127 West 3rd Street
Roswell, New Mexico 88201

Cortez City Library
802 East Montezuma
Cortez, Colorado 81321

Yoakum County Library
205 West 4th Street
Denver City, Texas 79323

Public Hearings

Public hearings will be held in Cortez, Colorado; Albuquerque, New Mexico; and Roswell, New Mexico. Times and locations will be announced.

CONTENTS

CHAPTER 1

DESCRIPTION OF THE PROPOSAL

HISTORY AND BACKGROUND

About one-third of the original oil in place (OOIP) in United States reservoirs is recoverable by conventional production methods. Conventional techniques include primary recovery (in which oil may flow to the surface or may be pumped if reservoir pressures are insufficient) and secondary recovery (in which a fluid, usually water, is injected to recover an additional fraction of the in-place oil).

Technological advances in enhanced oil recovery methods, commonly referred to as tertiary recovery, suggest that recovery of an additional 2.2 to 24.0 billion barrels of oil may result from the application of enhanced recovery techniques to existing reservoirs (Haynes et al. 1976).

Carbon dioxide (CO_2) flooding is one of the major enhanced recovery techniques, and is particularly well suited for relatively low permeability carbonate reservoirs such as those found in New Mexico and West Texas, particularly in the Denver Unit of the Wasson Oil Field. Laboratory research and field pilot projects have demonstrated that the injection of CO_2 into a reservoir that has been depleted by primary and secondary waterflood methods will mobilize the oil that has been trapped and retained in the rock by capillary forces. CO_2, which is miscible with the oil, displaces enough water to contact and then mobilizes the residual oil in the water-invaded portions. This oil can then be recovered. The CO_2 not trapped in the reservoir is produced with the well fluid and can be separated, recovered, and reinjected.

The proposed action involves the commercial application of CO_2 as a tertiary recovery method for the extraction of otherwise unobtainable oil from the Denver Unit of the Wasson Oil Field in West Texas. Shell Oil Company and Mobil Oil Corporation are the applicants.

The McElmo and Doe Canyon CO_2 well fields would exist on leases obtained by Shell and Mobil. The lease boundaries lie against one another over the entire proposed well fields. The total amount of leased acres is greater than the number of acres in the proposed CO_2 well fields. The boundaries of the CO_2 well fields include only those acres within the lease boundaries on which there are plans to drill CO_2 wells. The proposed CO_2 well fields are, therefore, smaller than the lease boundaries.

Both companies have unitized portions of the leased areas for more efficient development. Unitization is a means of consolidating development efforts of a number of adjacent leases. Units are formed

under cooperative agreement of lease holders by approval of the U.S. Geological Survey (USGS) under Part 226, 30 CFR. The CO_2 well field acreage is given in Table 1-1.

Table 1-1. APPROXIMATE ACREAGE FOR THE CO_2 WELL FIELD STUDY AREA

Component		Acres
Shell Doe Canyon Well Field		76,000
McElmo Dome Well Field		
Shell		101,000
Mobil		143,000
	Total	320,000

The lease expiration dates for all leases range from 1979 to 1989.

The U.S. Bureau of Land Management (BLM) and the U.S. Forest Service (USFS) have authority to issue oil and gas leases on public lands under Part 3100, 43 CFR. Issuance of oil and gas leases in the vicinity of the proposed CO_2 well fields has been covered by an Environmental Assessment Report (EAR). The report is the Sacred Mountain Oil and Gas Umbrella EAR, number 7-74, dated November 3, 1976. Issuance of individual leases is covered by a reference to this specific EAR with special stipulations unique to the tract in question attached as a supplement.

Drilling on issued leases is covered by a cooperative agreement between USGS and the BLM entitled: Secretarial Order 2948, "Cooperative Procedures Pertaining to On-Shore Oil, Gas, and Geothermal Resource Operations." Under this agreement, a drilling permit is sought from the USGS by the developer of the lease. The USGS informs the BLM of the application. A joint meeting is held by the representative of the BLM, USGS, the lease developer, and his contractor(s). The meeting is usually held on the site of the proposed well. The exact location of the well, access road, and the route of any pipeline or utility line are agreed upon during the meeting. A memorandum listing surface management stipulations and concurrence of the developer's surface use plan is furnished by the surface management agency to the USGS District Engineer. The USGS then completes the EAR covering the environmental impacts of the proposed well. The drilling permit is then issued. The USGS is the responsible agency for drilling operations within the lease. Authority for the USGS role is defined in Part 221, 30 CFR, "Oil and Gas Operating Regulations."

Shell and Mobil have drilled 20 exploratory wells by this procedure in the proposed McElmo Dome and Doe Canyon CO_2 well fields. The exploratory wells were drilled to determine the limits of the CO_2 project and the nature of the producing formation. Some of the wells drilled for exploration tapped CO_2 in quantities that would allow their use for production upon approval of the proposal. Others were either dry holes or poor producers, and were abandoned.

PROPOSED ACTION

The proposed project would be located in Colorado, New Mexico, and Texas. The proposed project includes development of CO_2 well field and gas-conditioning facilities in southwestern Colorado; construction of an interstate main CO_2 pipeline and associated microwave stations across parts of Colorado, New Mexico, and Texas; and development of facilities for receiving, injecting, recovering, and reinjecting CO_2 from the Denver Unit of the Wasson Oil Field in Texas.

PURPOSE AND OBJECTIVE

The purpose of the proposed action is to produce approximately 280 million barrels of oil from the Denver Unit of the Wasson Oil Field in West Texas. This oil would be recovered using the commercial application of CO_2 as a tertiary recovery method, since the available oil reservoir is being depleted by primary and secondary waterflood methods. It is anticipated that CO_2 flooding will deplete the available oil reservoir by about 2012. The CO_2 would be produced from well fields in southwestern Colorado by Shell Oil Company and Mobil Oil Corporation and transported to the injection field in West Texas via an interstate pipeline across parts of Colorado, New Mexico, and Texas.

The objective of the proposed action is to increase the nation's supply of oil for fuel, heat, electricity, and other uses while reducing the nation's dependency on foreign oil reserves. The 280 million barrels of oil to be obtained from the proposed action would produce an energy equivalent of 1.6×10^{15} Btu or 5.0×10^{11} kw-hr.* The average daily production of oil from this proposed project would equal about 0.3 percent of the September 1978 daily crude oil production in the United States or about 0.4 percent of the crude oil imported daily.**

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*One barrel of petroleum equals approximately 5.8×10^6 Btu or 1.70×10^3 kw-hr.

**Based on production and import statistics, <u>Oil and Gas Journal</u>, September 18, 1978.

LOCATION AND LAND STATUS

Map 1-1 shows the entire project area. See Appendix F, Maps F-1 through F-11, for specific details of the proposed CO_2 well field and pipeline.

The proposed project is located on or would directly affect 351,500 acres of federal, state, and private lands (Table 1-2). Federal agencies having jurisdiction for the approximately 194,830 acres (55%) of federal lands affected by the proposed project include the Bureau of Land Management (146,500 acres), Forest Service (45,050 acres), National Park Service (800 acres), and Bureau of Indian Affairs (2480). State lands and private lands include 870 acres ($<1\%$) and 155,800 acres (44%), respectively.

TIME FRAME

Schedules presented here and throughout the ES are assumed and are therefore subject to change. They were assumed in order to establish parameters for impact assessment purposes. Construction of the project would begin about January 1980 and peak in 1981. Operation of the facilities would commence about 1982 and continue for a projected 30 years. The time frame for construction and operation of specific aspects of the well field, pipeline, and oil field facilities is presented in Table 1-3.

PROJECT COMPONENTS

This section describes only those construction and operation aspects of the proposed project that were determined necessary for impact assessment.

Materials required to construct and operate project components would be transported to distribution points near the project area by truck and rail. From these as-yet-undetermined locations, the materials would be transported to the construction site via truck. Drilling fluids (muds and acid washes) would be trucked to the drilling location, and in the case of acid washes, injected directly from the transporting vehicle into the well. Construction workers would be transported to their work locations by buses and other surface means of transport.

No firearms would be permitted onsite by any construction personnel. Private landowners and lessees of public lands would be notified in advance of survey and construction.

CO_2 Well Field

The CO_2 well field in southwestern Colorado is divided into two areas: the McElmo Dome Field in Montezuma County and the Doe Canyon Field in Dolores County. The well field would consist of about 140 CO_2

Map 1-1. GENERAL LOCATION OF PROPOSED PROJECT

Table 1-2. LAND STATUS FOR THE PROPOSED CO_2 PROJECT

Land Status	CO_2 Well Field Study Area (acres)	Main CO^2 Pipeline System (miles)*	Main CO^2 Pipeline System (acres)**	Denver Unit Wasson Oil Field (acres)	Total (acres)	Total (%)
FEDERAL						
Bureau of Land Management	145,000	119	1,500	0	146,500	42
Forest Service	45,000	5	50	0	45,050	13
National Park Service	800	0	0	0	800	1
Bureau of Indian Affairs	1,500	81	980	0	2,480	1
STATE	0	72	870	0	870	1
PRIVATE	127,700	201	2,500	25,600	155,800	44
Total	320,000	478	5,900	25,600	351,500	100

*For pipeline right-of-way.
**Acreage includes right-of-way, origin station, compressor station, and communications sites.

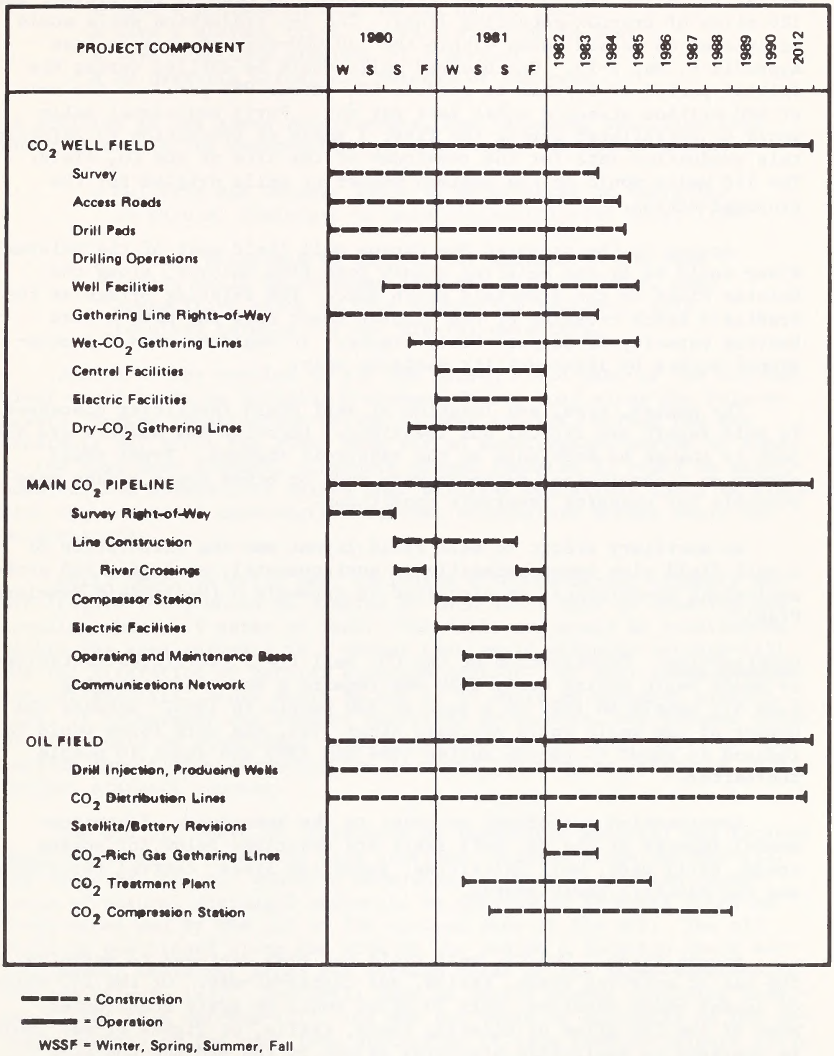


Table 1-3. PROPOSED TIME SCHEDULE FOR CONSTRUCTION AND OPERATION

wells, 192 miles of wet-CO_2 gathering lines, 13 central facilities, and 126 miles of dry-CO_2 gathering lines. The 140 production wells would be located on leased lands within the 320,000-acre study area (see Appendix F, Map F-1). One hundred wells would be drilled during the initial period of 3 years to produce CO_2 (about 99% pure) at the rate of 400 million standard cubic feet per day. Forty additional wells would be established during the first 3 years of production to maintain this production rate for the remainder of the life of the CO_2 field. The 140 wells would be the maximum number of wells drilled for the proposed action.

Access to the proposed Doe Canyon well field east of the Dolores River would be by the existing county road from Dolores, along the Dolores River to the Bradfield Ranch Road. The existing bridge at the Bradfield Ranch crossing of the Dolores River does not have a load bearing capacity to support heavy trucks. It would be used for occasional access by light utility vehicles only.

The number, type, and location of well field facilities discussed in this report are typical and idealized. Location and numbers are subject to change as knowledge of the reservoir changes. Types would change as technological advances were made or other types became more suitable for changing reservoir conditions.

An ancillary effort to well field layout was the elaboration of a well field plan based primarily on environmental, geologic, and archaeological constraints, as discussed in Appendix D (Well Field Development Plan).

Construction. Construction of the CO_2 well field facilities tentatively would begin during early 1980 and require a work force ranging from 315 people in 1980 to a peak of 530 people in 1983. Because the number of new wells would decrease after 1983, the work force would be reduced to about 60 people during 1984 and 1985 and about 10 people thereafter.

Construction procedures relevant to the assessment of environmental impacts at the CO_2 well field are described below for access roads, drill pads, well facilities, gathering lines, central facilities, and the electric power system.

Access Roads. The CO_2 well field has been designed to maximize the use of existing roads, trails, and rights-of-way. Of the 159 miles of access roads required, only 39 miles would be newly constructed. Most of the 120 miles of existing roads, trails, or rights-of-way would be upgraded to applicable standards as set by the BLM and the U.S. Forest Service (USFS) for roads built for construction-type vehicles. Roads would be constructed or upgraded to:

- support 40-ton loads
- have a minimum turning radius of 100 feet
- have a minimum travel surface width of 12 feet
- have a maximum gradient of 7 percent
- be passable during all seasons of the year

In addition to the above requirements, the following specifications would be met in the construction or improvement of access roads:

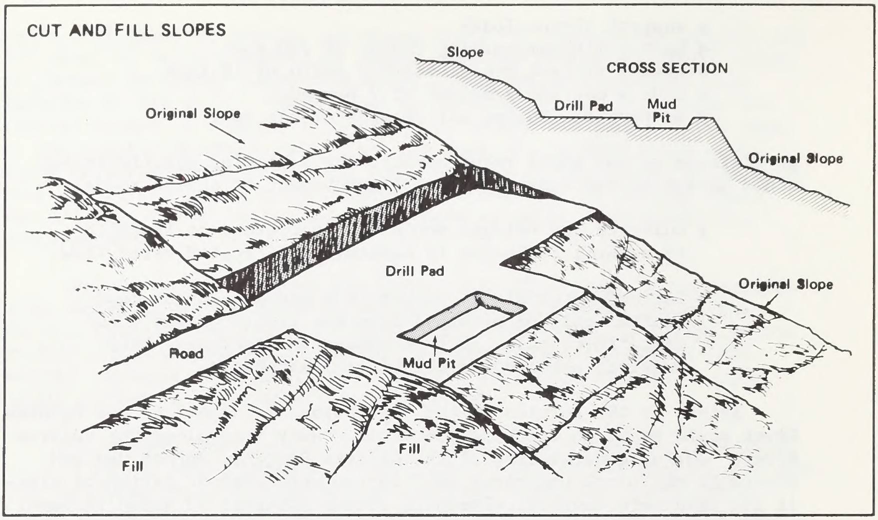
- Culverts and bridges would be constructed or installed in natural drainages to maintain anticipated water flow.

- Surface materials to support the maximum 40-ton load limits would be obtained from the rights-of-way, non-competitive sales or from commercial sources. USFS requires permits for all mineral materials.

Access to the portion of the Doe Canyon Field east of the Dolores River would be by an existing Montezuma County road along the Dolores River. During construction of the Dolores Project, McPhee Dam and Reservoir may block the river road for an undetermined period of time. If the road were blocked, alternate access (Chapter 8) would be used; however, the possibility exists that drilling operations could be timed with the reservoir construction so that alternative access would not be necessary.

Drill Pads. A drill pad, including a 16,000-barrel capacity mud pit (Figure 1-1), would be located at each drill site by clearing and leveling about 1.9 acres of land. The drill pad would be constructed within the area surveyed in a manner that would minimize cut-and-fill and the alteration of natural drainage courses. At well sites requiring cut-and-fill, banks would be cut at an angle to minimize erosion. Also, if topography and surface hydrology so require, the exposed faces of fill would be stabilized (with rock, riprap, netting, etc.) to keep surface runoff from degrading the face and introducing sediments into natural drainage courses.

The mud pit would be lined with an impervious material and located where it would be protected from erosion. On pads where cut-and-fill was required, the pit would be excavated in the fill portion (downslope of natural drainage) and would be surrounded by earth dikes on three sides and by the pad on the upslope side of the pit. The pit would be positioned along the side of the pad at a location where surface runoff would not erode the exposed faces of the dikes surrounding the pit (Figure 1-1). For drill pads on gentle slopes requiring leveling rather than cut-and-fill, the mud pit would be excavated on the upslope portion of the pad, thus protecting it from erosion (Figure 1-1). Gravel used to surface the drill pad would be obtained at the drill site or transported in from a commercial site.



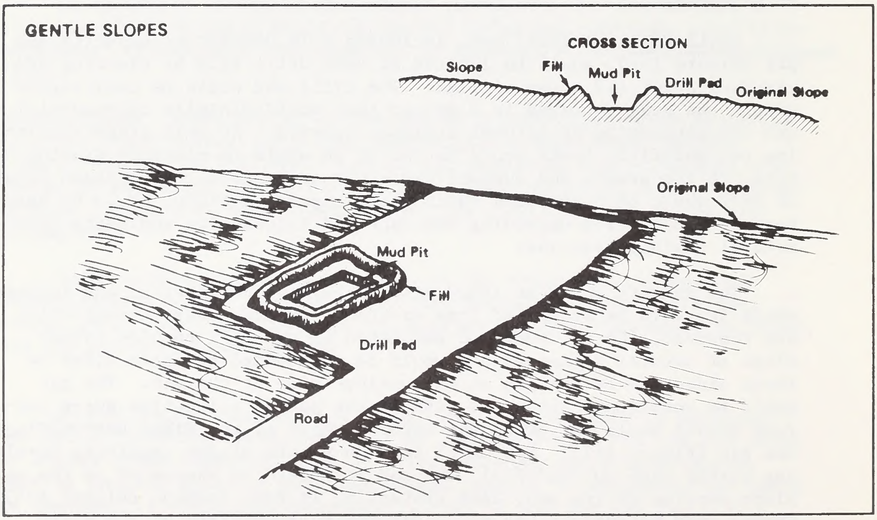


Figure 1-1. TYPICAL MUD PIT LOCATIONS

Drilling operations for each well would run 24 hours per day for about 45 consecutive days. As many as seven drilling rigs (Figure 1-2) would be used at the well field during the first two years of drilling. After the third year, only two rigs would be used until about 140 wells were completed (Figure 1-3). The only housing facilities associated with the drilling operations would be four trailer houses located in the well field to provide onsite quarters for supervisory personnel.

The drilling process uses freshwater bentonite and lime mud; another type of freshwater mud (containing a polymer, a starch, and a bacteria-cide); and is then replaced with a saltwater mud that may contain brine, calcium chloride, hydroxy-ethylcellulose, barite, a lignosulphonate, and calcium carbonate. The freshwater mud is discharged into the lined reserve mud pit, and the saltwater mud is used throughout the remaining drilling operation. A maximum of 273,000 gallons of fresh water would be required for drilling operations at each well; the water would be obtained either from a freshwater well(s) drilled by the applicants or by purchase from a local source.

Throughout drilling operations, several techniques would be employed or items installed to minimize potential effects on subsurface water supplies and formations. Installing and fully cementing the surface casing from about 2500 feet to the surface completely isolates the freshwater aquifers from any hydrocarbon reservoirs encountered. Each hole would then be drilled about 50 feet beyond the CO_2-producing formation. Cement would be circulated around the production casing (which may include a liner) from the bottom to about 500 feet above an easily erodible salt formation. To prevent hydrocarbons from entering the casing, cement would also be circulated to a level above any hydrocarbon formation. A completion rig would then be placed on each well. The casing would be perforated at the CO_2-producing interval and the interval treated with approximately 7500 gallons of 15 percent hydrochloric acid (HCl) per well to enhance CO_2 production. Some wells may require an additional stimulation technique using a 40,000-gallon sand fracture treatment. After stimulation, permanent tubing with a bottomhole packer would be installed in the well. The annular space between the tubing and casing would be filled with corrosion inhibitor. Installation of production tubing and packers within the casing provides an additional measure of isolation. This configuration permits the CO_2-producing formation to be effectively isolated from all other formations, thus eliminating the possibility of produced fluids affecting adjacent formations.

Water, drilling mud, and other liquids produced during completion and production operations would be transported to and disposed of in a disposal well (possibly a dry hole drilled during exploration operations). This disposal well would be cased in the same manner as a typical well and the same techniques that protect aquifers would be utilized. The

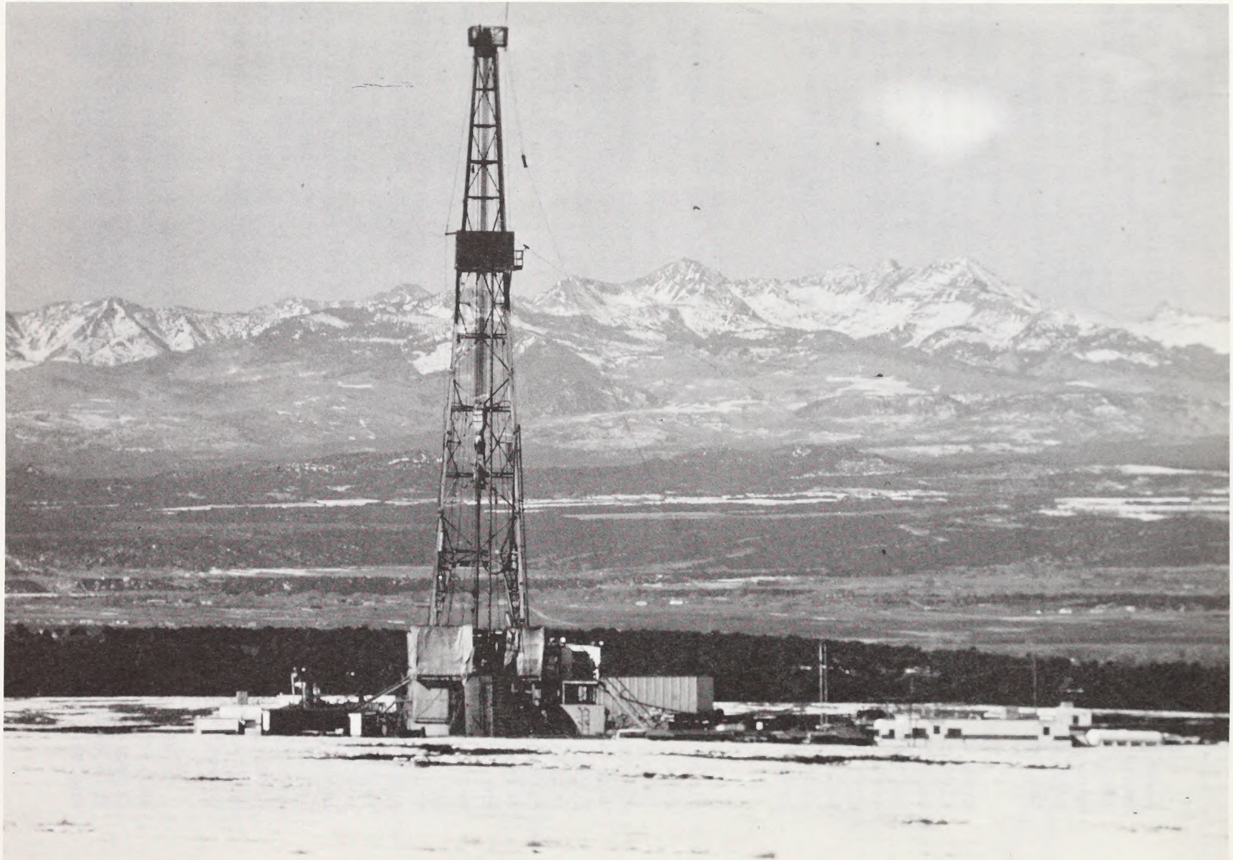


Figure 1-2. TYPICAL DRILL RIG

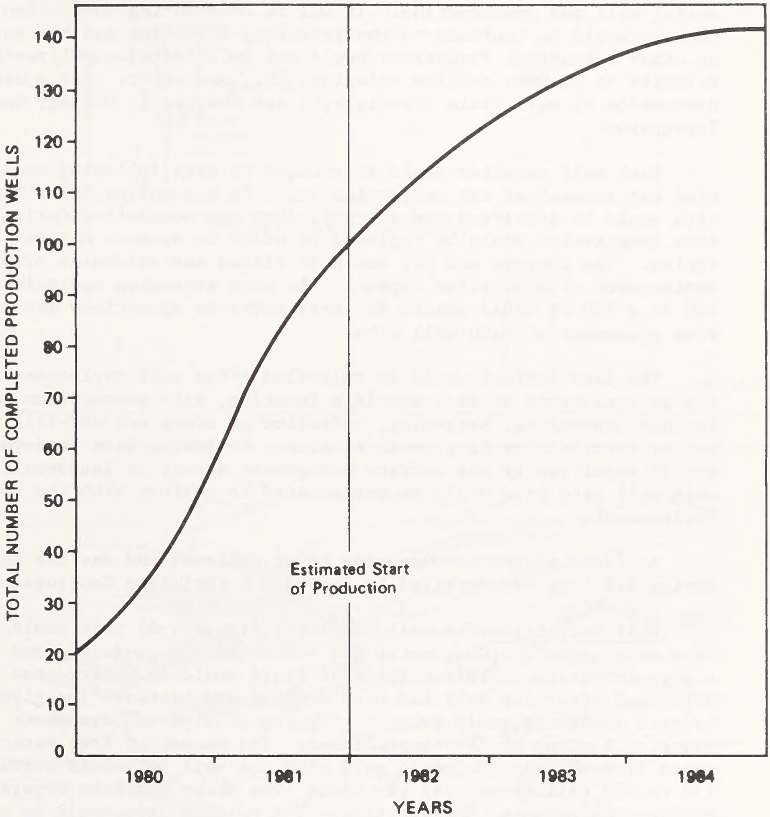


Figure 1-3. CO_2 PRODUCTION-WELL DRILLING PROGRESSION

fluids would be placed back into the CO_2-producing formation or one containing equal or lower quality fluid. Drilling fluids discharged to the reserve mud pit would be exposed until all liquids had evaporated or solidified. The exposed surface would then be covered with fill obtained during well pad construction. If HCl is used during completion operations, contact would be confined to the producing formation and the surface or other subsurface formations would not be affected. HCl reacts with dolomite to produce calcium chloride, CO_2, and water. For a detailed discussion of well field stratigraphy see Chapter 2, Geology and Topography.

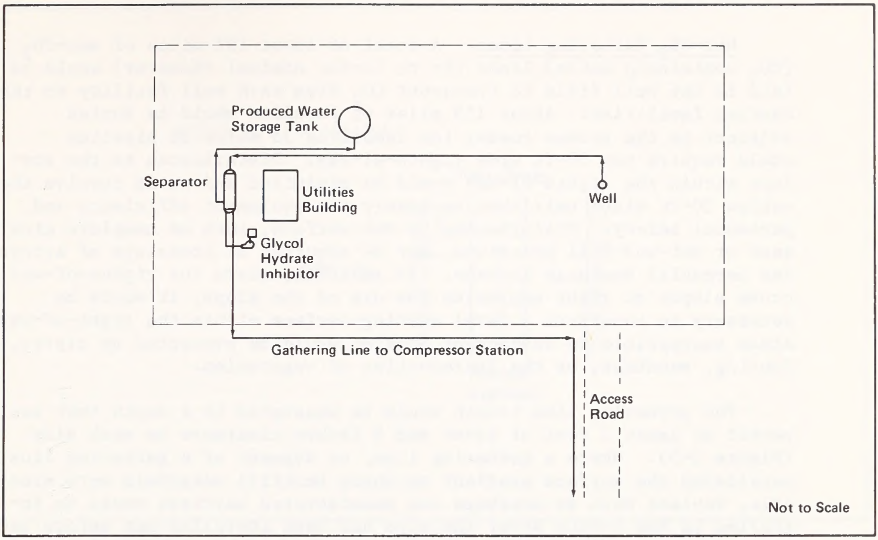
Each well location would be reduced in area following well completion and removal of the completion rig. To accomplish this, the location would be scarified and the soil that was stockpiled during drill site preparation would be replaced in order to promote natural revegetation. The reserve mud pit would be filled and releveled prior to replacement of stockpiled topsoil. An area averaging approximately 150 ft x 150 ft would remain for well workover operations and facilities placement at each well site.

The land surface would be releveled after soil replacement. Depending on conditions at each specific location, site restoration may also include contouring, terracing, reduction of steep cut-and-fill slopes and/or waterbarring to prevent erosion. Following site restoration, and if specified by the surface management agency or landowner, the unused well site area would be revegetated to conform with the surrounding environment.

Accident prevention measures to be followed and devices to be used during drilling are detailed in Appendix E (Drilling Contingency Plan).

Well Facilities. A well facility (Figure 1-4) that would remove free water from the CO_2, meter the volume of CO_2 produced, and inject a glycol-hydrate inhibitor into the fluid would be constructed on each drill pad after the well had been drilled and tested. The glycol-hydrate inhibitor would prevent plugging of pipe and equipment by CO_2 hydrates forming at low temperatures. The amount of free water separated from the wet CO_2 would vary with the well but would average about 150 to 200 gallons per day per well. The water would be separated to a 6000-gallon capacity holding tank. The holding tank would be emptied on a regular basis in the same manner as water used during drilling and completion.

The well facilities would be powered by an electrical system (see Well Field Electric Power System, below). Power lines to each well would be buried in the wet-CO_2 gathering line trench. All exposed facilities would be painted earth-tone colors to make them less visible. All equipment would be placed directly on the ground or on a concrete pad, depending upon foundation conditions.



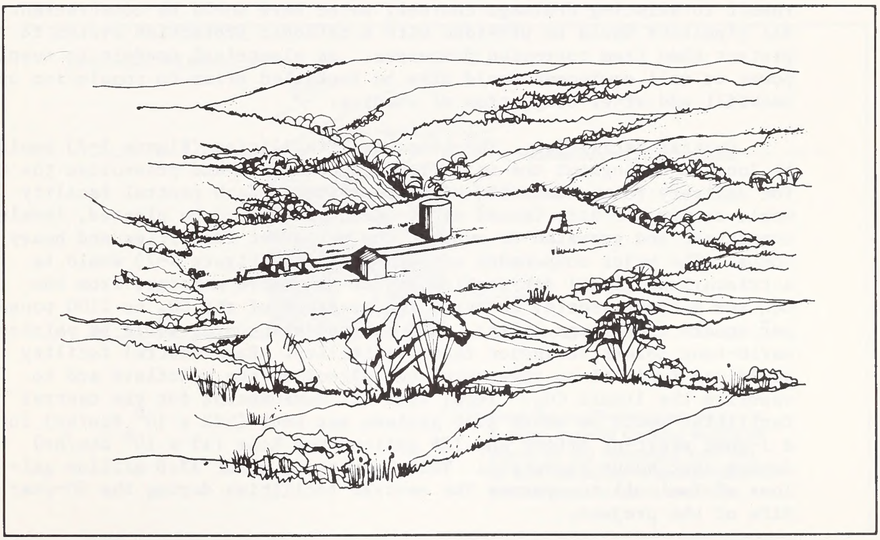


Figure 1-4. TYPICAL WELL FACILITY

Wet-CO_2 Gathering Lines. A total of about 192 miles of wet-CO_2 (CO_2 containing water) lines (4- to 12-in. nominal diameter) would be laid in the well field to transport CO_2 from each well facility to the central facilities. About 159 miles of pipeline would be buried adjacent to the access roads; the remaining 33 miles of pipeline would require new 50-ft wide rights-of-way. Disturbances to the surface within the rights-of-way would be minimized and would involve the entire 50-ft width only when necessary for equipment efficiency and personnel safety. Disturbances to the surface, such as complete clearance or cut-and-fill practices, may be required at crossings of arroyos and perennial drainage courses. In addition, where the rights-of-way cross slopes at right angles to the dip of the slope, it would be necessary to construct a level working surface within the right-of-way. Areas susceptible to subsequent erosion would be protected by riprap, fencing, sandbags, or the introduction of vegetation.

The gathering line trench would be excavated to a depth that would permit at least 2 feet of cover and 6 inches clearance on each side (Figure 1-5). Where a gathering line, or segment of a gathering line, paralleled the surface gradient or where backfill materials were erodible, devices such as sandbags and manufactured barriers would be installed in the trench after the pipe had been installed but before backfill operations were initiated (Figure 1-6). In order to divert surface runoff to existing drainage courses, water bars would be constructed. All pipelines would be provided with a cathodic protection system to protect them from corrosion processes. An electrical conduit to supply power to well equipment would also be installed prior to completion of backfill and after completion of shading.

Central Facilities. The 13 central facilities (Figure 1-7) would be located throughout the well field to condition and pressurize the CO_2 for delivery to the main CO_2 pipeline system. Each central facility would occupy a 5-acre fenced site. Each site would be cleared, leveled, compacted, and graveled to support the permanent facilities and heavy loads. The major components of each facility (Figure 1-7) would be a triethylene glycol dehydration system to remove moisture from the CO_2 and a compressor(s) to raise the pressure of the CO_2 to 2100 pounds per square inch gauge (psig). All exposed structures would be painted earth-tone colors to reduce their visibility. Each central facility would use fuel oil to regenerate the glycol in the reboilers and to vaporize the liquid CO_2. Total fuel oil consumption for the central facilities would be about 1036 gallons per hour (122×10^6 Btu/hr) for a 1-hour start-up effort and 128 gallons per hour (15×10^6 Btu/hr) during continuous operation. This amounts to about 33.8 million gallons of fuel oil to operate the central facilities during the 30-year life of the project.

Fuel storage tanks would be situated in an area surrounded by an impermeable dike and basin capable of containing 125 percent of the

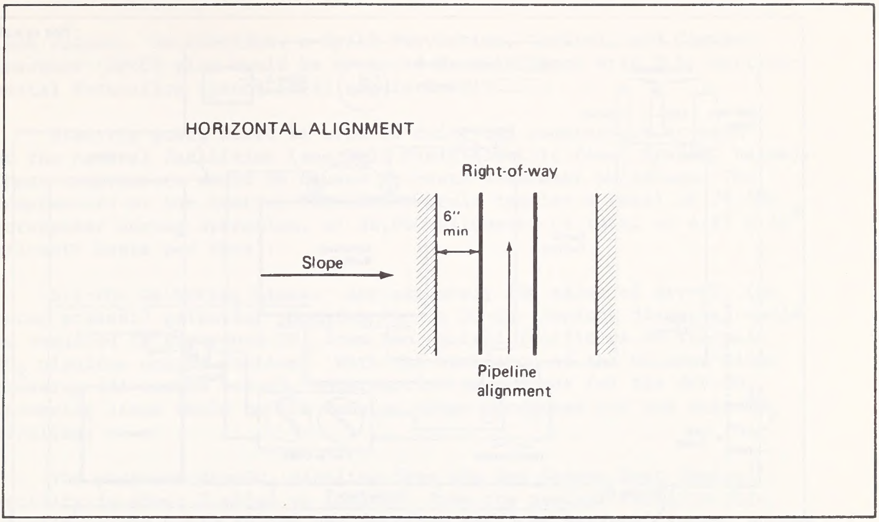


Figure 1-5. POSSIBLE CO_2 GATHERING LINE ALIGNMENTS

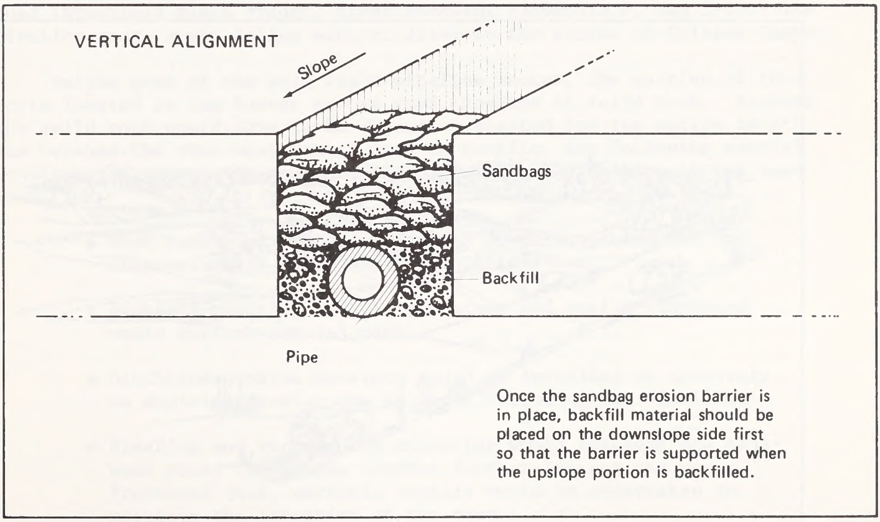
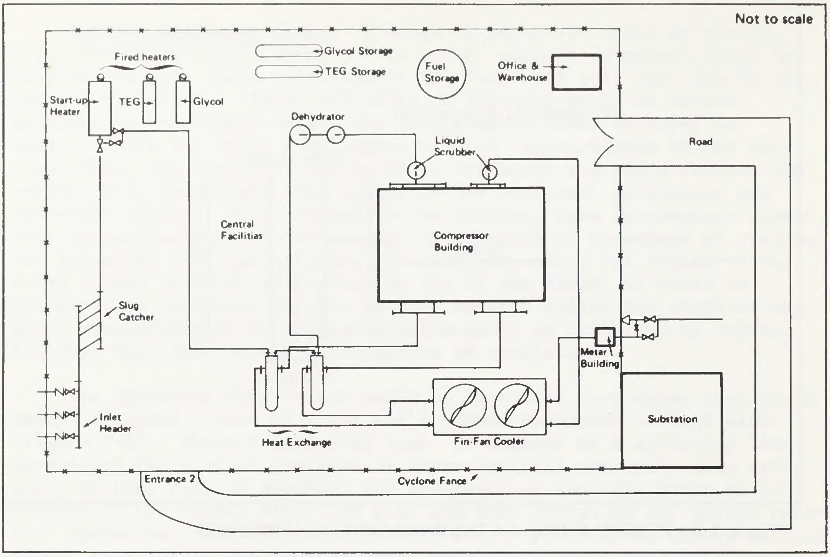


Figure 1-6. TYPICAL TRENCH-LINE EROSION BARRIER



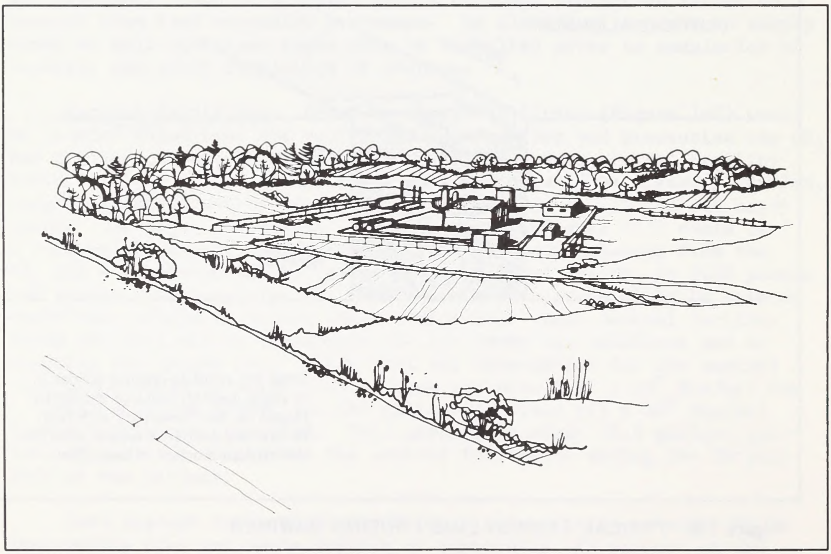


Figure 1-7. TYPICAL CENTRAL FACILITY

tank volume. In addition, a Spill Prevention, Control, and Countermeasures (SPCC) plan would be prepared in accordance with U.S. Environmental Protection Agency (EPA) regulations.

Electric power would be used to drive the compressors at each of the central facilities (see Well Field Electric Power System, below). These compressors would be housed in sound-retardant buildings. The compressors at the central facilities would require a total of 74,500 horsepower during operation, or 56,000 kilowatts (a total of 4.87×10^8 kilowatt hours per year).

Dry-CO_2 Gathering Lines. Approximately 126 miles of dry-CO_2 (no water present) gathering pipeline (6- to 20-in. nominal diameter) would be required to transport CO_2 from the central facilities to the main CO_2 pipeline origin station. With the exception of the Dolores River crossing (discussed below), construction procedures for the dry-CO_2 gathering lines would be the same as those discussed for the main CO_2 pipeline.

The proposed dry-CO_2 pipeline from the Doe Canyon East Central Facility is about 7 miles in length. From the central facility this pipeline route would follow the existing San Juan National Forest Access road southwesterly for about 2 miles. At this point it would trend westerly, crossing the river about 2 miles downstream from the access road (Bradfield Ranch bridge) river crossing (Appendix F, Map F-1). The pipeline route would follow natural draws on the slopes of Dolores Canyon.

Unlike most of the well field pipeline routes, the portion of this route located in the forest access road consists of solid rock. Because the solid rock would have to be ripped or blasted for the entire length and because the road must remain open to traffic, the following special construction techniques would be employed while laying pipe in the road bed:

- Rock removed from the ditch-line would be hauled off and disposed of in an authorized location.
- Backfill material that is competent and easily compacted would replace removed rock.
- Ditchline erosion barriers would be installed at intervals to minimize erosion due to water following the ditchline.
- Blasting and ripping the ditchline would fracture the adjacent rock. As future traffic further loosens the newly fractured rock, periodic repairs would be undertaken to maintain the integrity of the road.

- In some locations, the construction spread would have to utilize the entire width of the road, thus disrupting traffic for short periods of time.

The remaining portion of the line would require a 60-ft cleared right-of-way except for the buried river crossing where a 200 x 200-ft clearance would be required on each side of the river for equipment storage and work area. Upon completion of construction, only 40 feet of the right-of-way would be kept clear of trees. Grasses and low-growing shrubs would be allowed to grow across the entire right-of-way. This shrubbery and some trees would be strategically placed so as to block the view of the right-of-way from critical viewsheds. In addition, where the right-of-way passed through heavy vegetation, the edges would be feathered and its route zig-zagged in order to eliminate the "channeled" effect.

Well Field Electric Power System. The 13 central facilities and approximately 140 well facilities would require electric power provided by Empire Electric Association of Cortez, Colorado. The electric power system for the well field would consist of 14 new substations, one at each of the 13 central facilities and one located northeast of Cahone; 2 new switching stations, one west of Pleasant View and one located southeast of Cahone; and 86 miles of new 115-kv transmission lines (Appendix F, Map F-1). Operation of the project would require approximately 5.36×10^8 kilowatt hours of electricity per year in Colorado and New Mexico. This amount is well within the capacity of the electrical utilities to supply additional power. No new generative facilities would be required by the project. The wood-pole H-frame structures used in the transmission line system would require minimum disturbances to the surface since most of the routes would permit blade-up operation (i.e., the terrain and vegetation in the right-of-way are such that access is possible without blading a trail or access road). In some areas of very rough terrain or dense vegetation at least 2 feet high, a truck road may be needed to provide access to the right-of-way and tower sites. An area of about 50 ft x 100 ft is required at each pole site to provide suitable working space for equipment and assembly of the poles. Most trees and tall shrubs would have to be cleared from the pole site to provide a suitable assembly pad. The construction specifications would meet requirements of the National Electric Safety Code (NESC). Design of the power poles would conform to "Suggested Practices For Raptor Protection on Powerlines" (Miller et al. 1975) to minimize raptor electrocutions.

Reclamation including reseeding would be conducted on cleared areas when required by landowners or the appropriate surface management agency.

Operation. A small warehouse and office building would be located at a central facility to serve as the operating and maintenance base for the CO_2 well field area. Access to CO_2 wells would be required at all times to provide for well surveillance, mechanical repairs, produced-water hauling, and well workover and stimulation work. Operation and maintenance procedures would require a work force of about 40 people for the life of the project. No additional land requirements or disturbances to the surface would be required during operation of the CO_2 well field facilities.

Main CO_2 Pipeline

This portion of the proposed project provides information about the construction and operation of those facilities associated with transporting the CO_2 from the well field area in southwestern Colorado to the injection field in West Texas.

Changes in throughput rates and additional discoveries of CO_2 may require changes in certain pipeline design parameters. The pipeline design could be modified to accept larger amounts of CO_2 by increasng the pipe diameter before construction or compressor station horsepower during or after construction. These modifications could be incorporated into the design separately or in conjunction with one another. Design changes would depend upon the quantity of CO_2 to be transported above the proposed 400 million standard cubic feet per day. Even if both potential design changes are incorporated into the pipeline, there would be no additional environmental impact. Any changes in the size of the pipe would be made prior to construction.

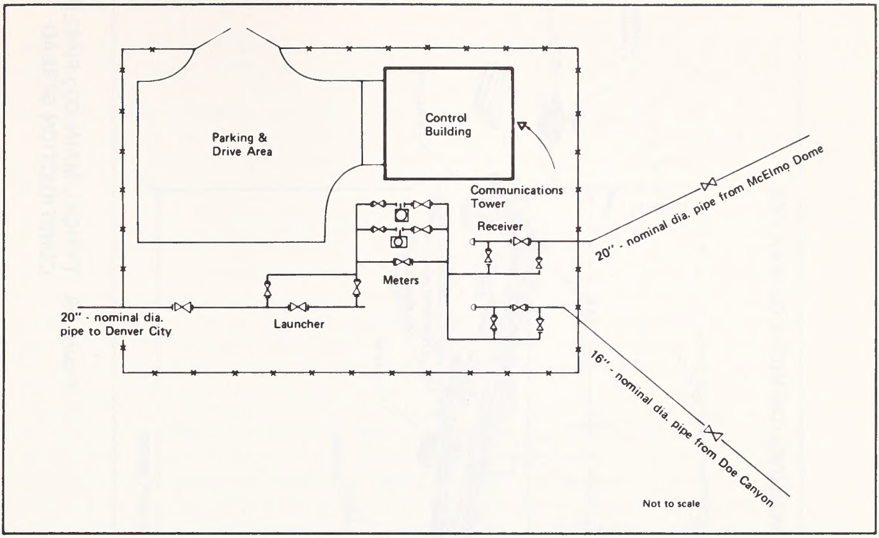
The installation of larger diameter pipe would be accomplished by the same techniques to be employed on the proposed 20-in. diameter pipe and would require the same number of construction personnel. The only difference would be trench width (the trench would be 1.5 feet wider than the diameter of the pipe and thus would vary with pipe sizes). The proposed pipe diameter of 20 inches would require a 3-ft wide trench, which would be 1.5 feet wider than the pipe. Likewise, a 54-in. trench would be required for a 36-in. pipe. The installation of higher horsepower or more compressors could be accomplished with the proposed 115-K power supply. Changes in the horsepower of the proposed compressors could be done at any time prior to operation.

Construction. The main CO_2 pipeline and associated facilities tentatively would be constructed in 1981 and 1982. This construction would require an initial work force of 1255 people with a peak of 1355 people. The main CO_2 pipeline facilities would consist of an origin station, pipeline, compressor station, communications network, and electric power system (see Appendix F, Maps F-2 through F-11).

Origin Station. The origin station would be located at Milepost (MP) 0 (see Appendix F, Map F-3) to receive the CO_2 from the well field. This station would consist of a valving system to receive the dry CO_2, a metering system, pigging facilities, and a control building (Figure 1-8). The origin station would be located on level terrain and would require a clearing of about 400 ft x 400 ft (about 4 acres). Clearing and construction techniques would be similar to those already discussed for central facilities in the well field.

Pipeline. The CO_2 would be transported in a 20-in. diameter, 478-mile long pipeline at pressures between 1400 and 2100 psig. Peak construction of the pipeline would be accomplished by as many as five construction teams (spreads) (Figure 1-9) working concurrently for about 3 months each over a 1-year period on segments of the pipeline about 100 miles in length. The anticipated locations for these construction teams are Cortez, Colorado; and Farmington, Albuquerque, and Roswell, New Mexico. Construction activities would be confined to a 100-ft right-of-way (Figure 1-10) along the proposed route. Approximately 91 percent (438 miles) of this route is adjacent to existing pipeline rights-of-way (see Appendix F, Maps F-2 through F-11). The remaining 40 miles of pipeline would not be adjacent to existing rights-of-way. Between MP 19 and MP 34, 15 miles of right-of-way would pass through relatively undisturbed country. Between MP 95 and MP 109, 25 miles of right-of-way would pass through the already highly developed San Juan Oil and Gas Field. Typical construction activities would require clearing about an average 50-ft width of trees, brush, and boulders to allow safe and efficient operation of construction equipment. In some areas of rough terrain the entire 100-ft right-of-way width might have to be so cleared of trees, brush, boulders, and like obstructions. Clearance would be the minimum necessary for safe and efficient construction practices. Existing road crossings would be used to provide access to the right-of-way for materials and machinery so that no new access roads would be required. In remote areas where there are no existing access roads, the right-of-way would be the primary path for surface travel during pipeline construction. A 200 x 200-ft storage area would be required on both sides of river crossings, highway crossings, and railroad crossings.

To ensure that vehicles may safely traverse the right-of-way, it may be necessary to construct bridges or culverts across creeks and arroyos on the working side of the right-of-way when permitted by the federal surface management agency or the landowner. Also, materials may be cut away and filled elsewhere (cut-and-fill). Should such methods be required, materials for approaches and fill would be obtained (1) from the right-of-way; (2) from commercial sources, then transported to the location; or (3) from adjacent lands when permitted by the federal surface management agency or the landowner. Grading would be performed in such a manner as to minimize effects on natural drainage. On steep terrain or in wet areas, where the right-of-way must be graded at two elevations (two-toning) or diversion dams must be



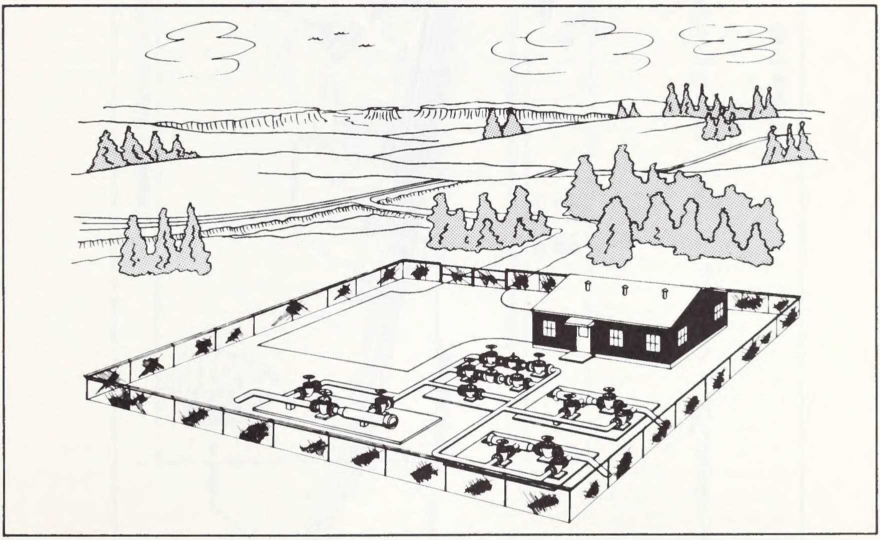


Figure 1-8. ORIGIN STATION

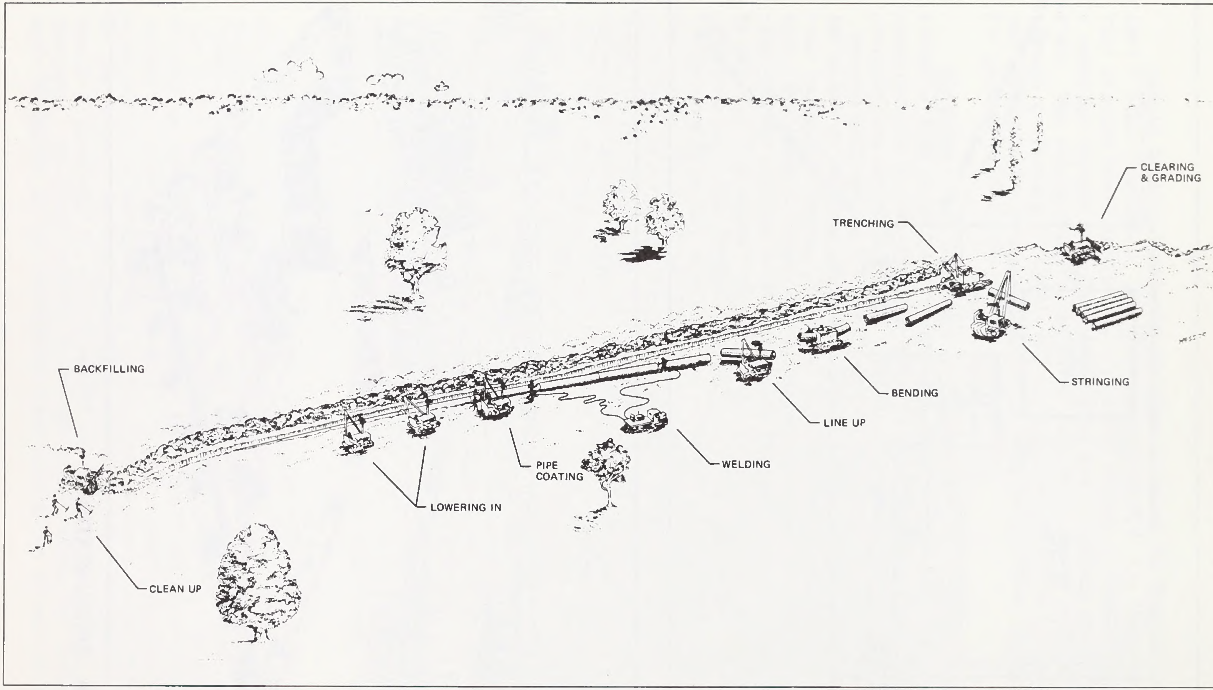


Figure 1-9. TYPICAL MAIN CO_2 PIPELINE CONSTRUCTION SPREAD

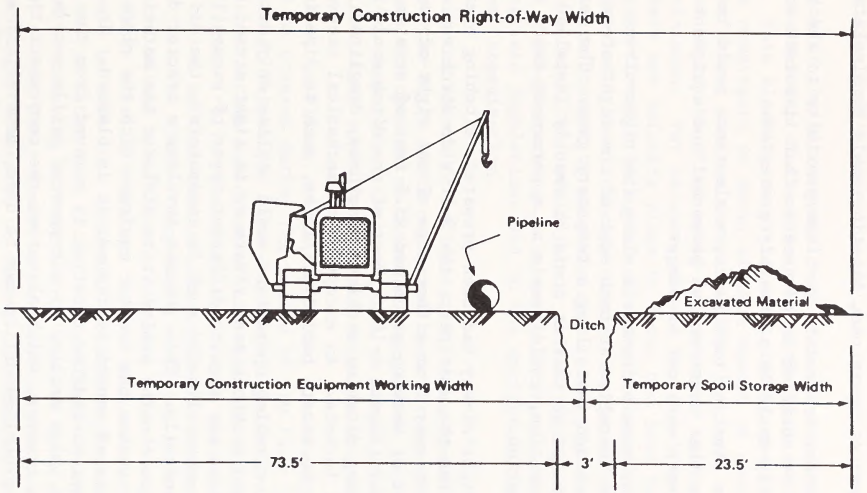


Figure 1-10. CONSTRUCTION RIGHT-OF-WAY USE

built to facilitate construction, the areas would be contoured upon completion of construction to resemble the original grade.

Should blasting be necessary, the following safety precautions would be adhered to in all instances:

- In areas of human use, blasting would be blanketed (matted).
- Landowners or tenants in close proximity to the blasting would be notified in advance so that livestock and other property could be adequately protected.
- Before blasting took place, a clearance would be made to ensure that construction personnel and equipment and local residents were out of danger.

Where fences were encountered along the right-of-way, adequate bracing would be installed at each edge of the right-of-way prior to cutting the wires and installing a temporary gate. The temporary gate would be constructed so that it could be readily installed and, at the landowner's discretion, could remain as a permanent fence upon completion of construction.

Once the right-of-way had been prepared, ditching operations would be initiated. For the most part, the 3-ft wide ditch would be centered on a line 25 feet away from either edge of the right-of-way, thus providing 73.5 feet of working space and 23.5 feet of area in which to store ditch spoil (Figure 1-10). Most of the ditch would be excavated mechanically using ditching machines, backhoes, draglines, and cranes with clam-shell buckets. An exception to mechanical excavation would be hand-digging to locate buried utilities, such as pipelines and cables.

Generally, ditching operations would utilize only ditching machines in open areas and backhoes near rivers or in tight areas; however, subsurface conditions may require different types of excavation. In areas where loose or unconsolidated rock is encountered, the ditch line may be ripped mechanically. This process involves a tractor dragging a long shank (ripper-tooth) behind it to dislodge the material. Often, another tractor pushes the tractor equipped with the ripper. If the material encountered cannot be ripped, it is blasted. In preparation for blasting, unconsolidated material is removed from the ditch line and a series of holes drilled by air-powered drills generally suspended from a sideboom tractor, which also tows the compressor that supplies the air. Self-propelled drills may be used, however, if a significant amount of drilling is to take place in one location. The previously discussed safety measures would be taken before any blasting occurred during the proposed project.

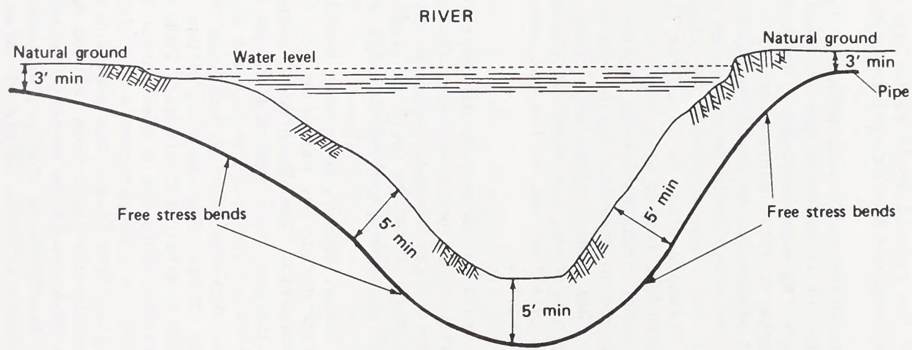
Subject to agreements with landowners and surface management agencies, topsoil removed during ditching operations would be saved. An

angle-bladed bulldozer or motorgrader would precede the ditching machine and cast the topsoil to the working side of the right-of-way (Figure 1-9). The ditching machine would then cast the ditch spoil to the opposite, or spoil, side of the right-of-way so that the two soils would remain separate. The ditch would be backfilled upon completion of construction, and the topsoil would go in last to return it to its original position and enhance the natural revegetation process.

The depth of the ditch would vary with the conditions encountered. The cover from the top of the pipe to ground level would generally be 4 feet thick. When blasting occurred near private dwellings or in areas where people congregate or work, minimum amount of cover would be 2.5 feet; in open areas, minimum cover would be 1.5 feet. There would also be situations where the ditch would be excavated to depths greater than the stated minimums. For example, should the pipeline traverse areas for which there are definite plans to level the land for irrigation or other purposes, it would be buried at a depth that would permit the land to be leveled. When crossing canals, borrow ditches, or irrigation ditches that are dredged to maintain depth, the pipeline ditch would be excavated to a depth that would permit safe dredging operations. At railroad and highway crossings, the depth of the ditch would conform to the appropriate regulations and to the desires of the appropriate jurisdictional organization.

To reduce the hazard of accidents, ditching operations would be timed so that the ditch would not stand open for an extended period. In areas where the open ditch crossed range animal paths, driveways, or rural roads, temporary crossings (such as plank bridges and unexcavated ditch line) would be provided for safe and unimpeded passage.

The Mancos, La Plata, Animas, San Juan, Rio Grande, and Pecos rivers would be crossed during the period of low flow (generally from September through February). The ditch would be excavated to such a depth that scour action would not affect the pipe during periods of high water (Figure 1-11). The ditch would be a minimum of 4.5 feet wide at the bottom so that the coating would not be damaged when lowering the pipe into the ditch. Sag bends on either side of the river would be placed inland a sufficient distance from the river bank to ensure that water erosion would not expose them. Construction of water crossings would be made in a manner that would minimize the effects of construction on water flow (i.e., the gradient of the stream would be maintained by removing all spoil from the bed upon completion of construction; stream banks would be restored to resemble their original grade; and sandbags, breakers, or riprap [revetments] would be placed over the pipeline where required). Where situated under water, the pipeline would be weighted to ensure that it remained in the ditch. Construction of stream crossings would be made during periods of lowest waterflow or no flow, depending on the stream.



Note: The burial depth shown is where the river bottom materials are earth, sand or gravels.

Figure 1-11. RIVER CROSSING

Road beds that support paved roadways or railroads would generally be crossed by boring a hole beneath the bed rather than by ditching across the surface. Casing would be installed at crossings where required by federal, state, local, or railroad authorities.

Stringing, bending, welding, coating, and lowering the pipe are phases of pipeline construction that generally follow right-of-way and ditching operations; they do not involve additional commitments or alterations of the right-of-way or the ditch.

The pipe would be strung along the right-of-way ahead of ditching operations, except in areas requiring blasting. It would be coated with protective materials and lowered directly into the ditch. In rocky areas, the bottom of the ditch would be padded to provide a uniform bearing for the pipe, and once it was in the ditch, it would be padded with fine materials where necessary to protect the wrap during backfill operations.

Backfilling would be done in a manner that would ensure that the space below and beside the pipe would be completely filled with loose materials. Backfill material that could not be placed in the ditch would be crowned on top of the ditch to compensate for future settling. If the backfill material needed compacting it could be flooded, tamped, or walked-in with a wheeled vehicle.

Once the ditch had been backfilled, the right-of-way and any other area affected would be cleaned up. The right-of-way would be graded and fences repaired. In areas where topsoil had been salvaged, it would be moved to its former position on top of the ditchline to enhance the natural revegetation process.

All disturbed surfaces would be contoured to resemble their preconstruction grade. If required, revegetation would be done meeting the requirements of the owner or surface management agency. Erosion-control devices would be constructed on steep slopes on the right-of-way and along any cuts made through unconsolidated materials. Erosion-control devices that may be employed include (but are not limited to) water bars, riprap, terracing, and sandbags.

The pipeline would be protected by the pipe coating, rectifiers, and anodes in order to minimize corrosion of the pipeline material.

Sections of pipe to be placed beneath railroads, highway rights-of-way, and rivers would have all welds radiographically inspected before installation. The entire pipeline would be hydrostatically tested to 125 percent of maximum operating pressure. Possible sources of water for hydrostatic testing include: (1) the Dolores River, (2) Narraguinnep Reservoir, (3) the Animas River, (4) the San Juan River, (5) the Rio Grande, and (6) the Pecos River. The water would be

obtained through agreements negotiated with the local authorities controlling the water resources. The estimated amount of water required for testing ranges from 12 to 24 acre-feet per spread. The exact amount required depends on testing procedures used. The test water would be disposed of in accordance with federal, state, and local agency requirements.

Compressor Station. The main CO_2 pipeline would require one compressor station located in Sandoval County, New Mexico at MP 150 (see Appendix F, Map F-5). This compressor station would occupy about 8 acres (600 ft x 600 ft) of land. Clearing and construction techniques would be similar to those previously discussed for the central facilities at the CO_2 well field. The three main compressors would be electrically powered and rated at 2500 horsepower each. The approximately 5,600 kilowatts of electricity needed to power these compressors would not require any new power generating plants. Standard electrical transmission lines would supply power to this station.

Communications Network. The communications facilities would consist of a mobile radio system and a microwave network of about 14 repeater stations located at irregular intervals along, but not within, the pipeline right-of-way (see Appendix F, Maps F-2 through F-11). Each repeater site typically would consist of a small building (8 ft x 10 ft) containing the equipment, a guyed tower with mounted antenna hardware, an entrance road, and fencing (Figure 1-12). This equipment would provide voice, data, and pipeline control circuits in addition to mobile radio communications along the pipeline.

The microwave system would be routed to take advantage of the higher elevations and existing towers along the route in order to minimize tower height, to permit longer distances between repeater stations, and to minimize new construction. Towers presently located on Menefee Peak, Huerfano Mountain, Haystack Mountain, Sandia Crest, and at the Wasson Oil Field would be utilized. Tower heights would range from 10 feet for mountain-top locations to 160 feet for those on flat terrain. All new sites would be adjacent to existing access roads and electric power sources; the average length of electric power loops is 130 feet, ranging from 30 to 316 feet.

Pipeline Electric Power System. Electric power supplied by the Plains Electric Generation and Transmission Cooperative, Inc., Albuquerque, New Mexico, is needed to operate the mainline compressor station in Sandoval County, New Mexico. A new switching station and substation would be required at the compressor station. Approximately 6 miles of new 115-kV transmission line would be installed to connect the compressor facilities with the existing Plains transmission line (Map 1-2). Land requirements for the electric power system consist of approximately 2 acres for the switching station and substation and 73 acres for the transmission line. Construction procedures for the

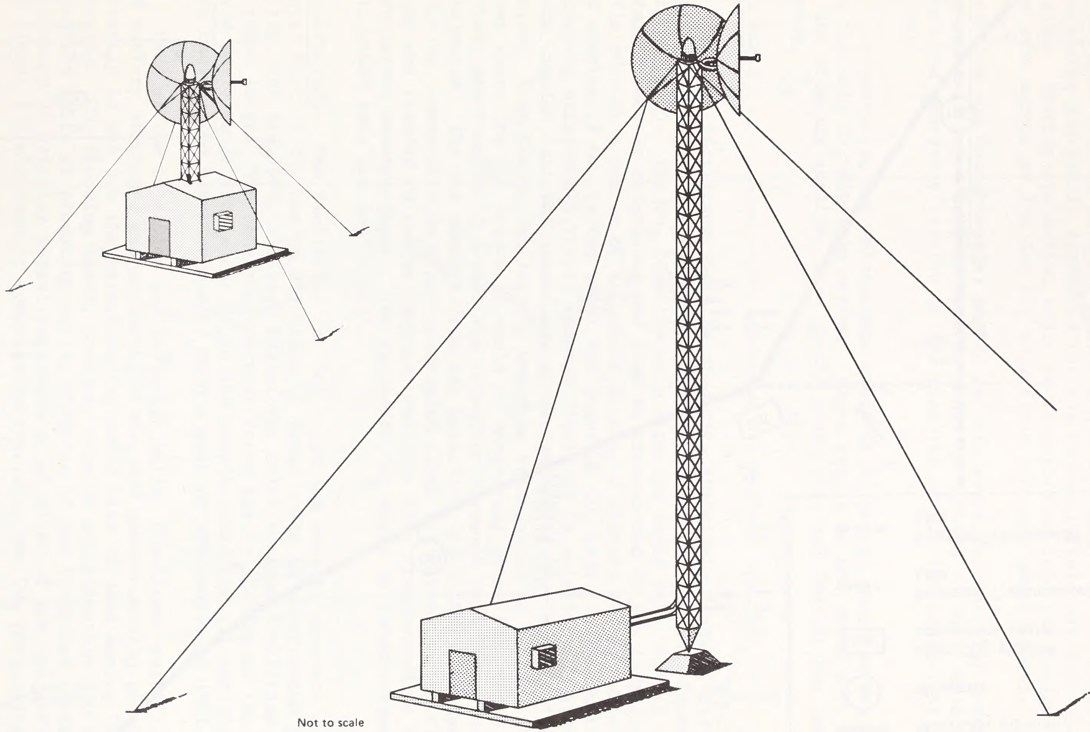
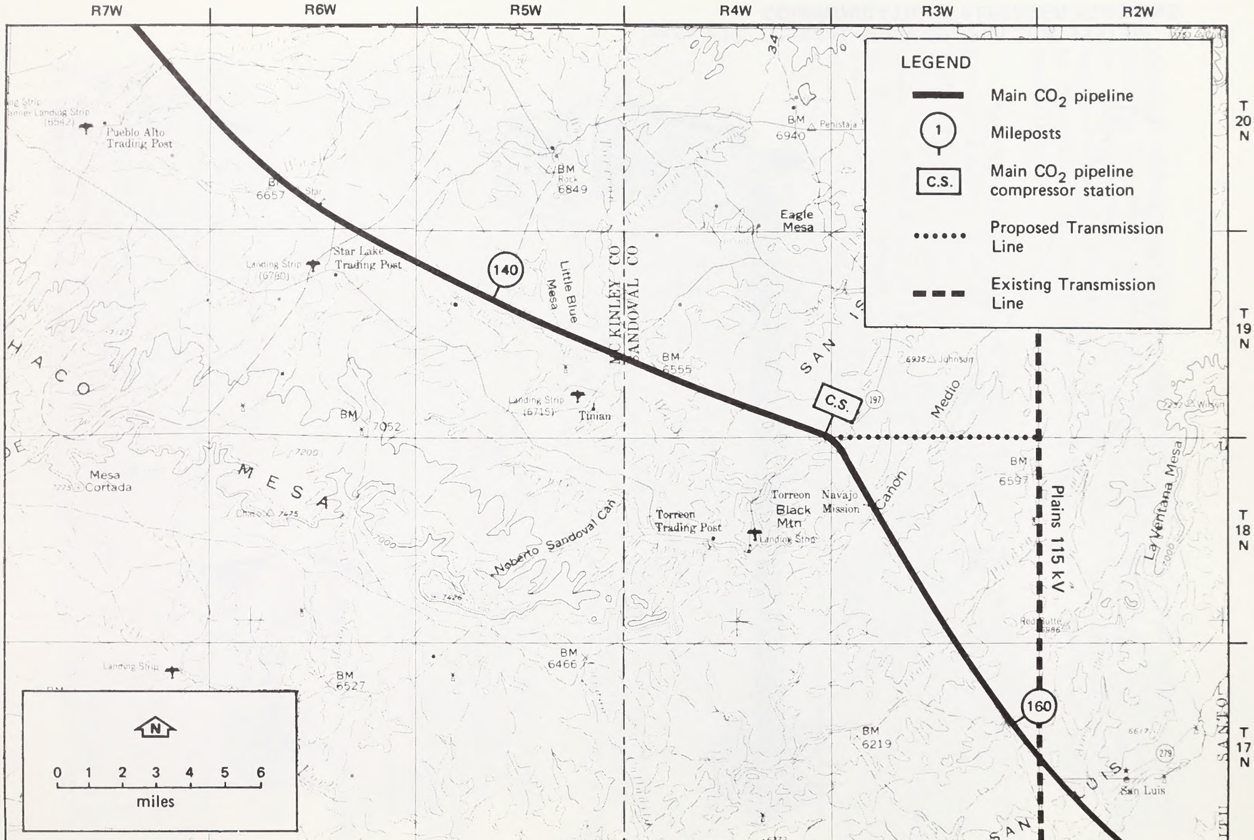


Figure 1-12. TYPICAL MAIN CO_2 PIPELINE SYSTEM COMMUNICATIONS REPEATER STATIONS



Map 1-2. TRANSMISSION LINE ROUTE FOR THE PROPOSED MAIN CO_2 PIPELINE COMPRESSOR STATION

double-pole H-frame wood structures would be similar to the construction procedures previously discussed for the CO_2 well field electric power system. (Raptor protection would be incorporated into the design in the same manner as for the CO_2 well field electric power lines).

Operation and Maintenance. Aerial patrols would periodically inspect the right-of-way. Surface traffic would be limited to valve maintenance and emergency repairs to the pipeline or erosion control structures.

An operating and maintenance staff of 24 people would be required for the main CO_2 pipeline system: eight people on the north end, seven at the midpoint station, five at the south end, and four at the control center.

Oil Field

Several facilities would be needed to distribute, inject, and recover the CO_2 at the Denver Unit of the Wasson Oil Field in Texas (Figure 1-13). The CO_2 from the main pipeline would pass through the terminal booster compressor and then be transported to the injection wells through a series of injection lines. A mixture of oil, water, and eventually CO_2 (after about two years of CO_2 injection) from the producing wells would travel through flowlines to satellite stations where liquids (oil and water) and gases (including CO_2) would be separated. From there, the liquids would be transported to battery stations where the oil and water would be separated; water from these battery stations would travel via injection lines to well sites to be reinjected. The gas mixture from the satellite and battery stations would be transported to a gas-processing plant via gas-gathering flowlines and treated to remove hydrogen sulfide, then transported to a hydrocarbon removal plant. The recovered CO_2 would be recompressed and reinjected into the Denver Unit.

Construction. New facilities for CO_2 injection and oil recovery at the Denver Unit of the Wasson Oil Field in Texas would be constructed primarily during 1981 and 1982, although additional units to some facilities would be added later. The construction work force for facilities at the oil field would range from about 20 to 480 people (assuming all facilities were constructed simultaneously) with a peak of 480 people in 1981.

Many of the injection and producing wells, flowlines, satellite and battery stations, gas-gathering lines, and gas-processing plants presently in use for the waterflooding would also be used during CO_2 flooding. CO_2 flooding would, however, require approximately 100 new injection wells or producing wells, 25 miles of new flowlines, modifications to 34 existing satellite stations, 42 miles of new gas-gathering lines, 5 field booster compression stations, one CO_2 processing

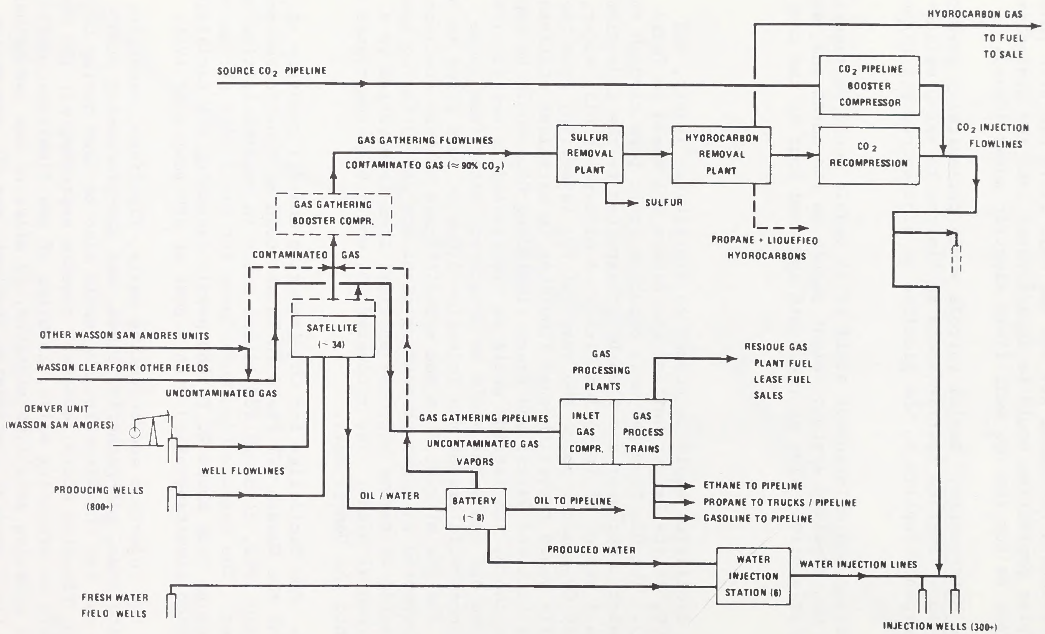


Figure 1-13. SCHEMATIC DIAGRAM OF MODIFIED FACILITIES AT THE DENVER UNIT

plant and injection compressor station, and 100 miles of new injection pipelines.

Construction procedures for these facilities are essentially the same as the construction procedures previously described for the well sites, various pipelines, and building sites such as the central facilities and compressor station proposed for the CO_2 well field in Colorado.

Some of the facilities would be constructed prior to CO_2 injection; others would be constructed in phases or during the life of the project because of the time interval required before the injected CO_2 breaks through into the producing wells and the long period over which CO_2 production increases (Table 1-3). In general, new well sites and associated pipelines would be constructed continually.

The gas-processing plant would most likely be built in two phases. The first phase would occur prior to CO_2 injection and would last about 12 months; the second phase of construction would take place 5 to 7 years later when the amount of CO_2 recovered from the producing wells approached peak rates.

The gas-gathering compressor stations would consist of a number of compressor units added over the years to accommodate increases in produced gas rates. The compressor station at the processing plant for the recycled CO_2 would also be under continual construction with the addition of new units as the produced gas rate increased.

Energy for CO_2 compression and processing facilities would consist mostly of natural gas. Some electrical energy supplied by the current supplier (Southwestern Public Service Company of Amarillo, Texas) would also be needed for small pumps, motors, lights, etc. The natural gas would be used to operate the CO_2 compressor station that would compress the CO_2 to an injection pressure of 2000 psig. An estimated 120,000 horsepower may be required to maintain compression throughout the unit.

<u>Operation and Maintenance</u>. Operation and maintenance of the facilities at the Denver Unit would not require any additional land disturbance but would consist of about 120 employees traveling to and from the facilities on a daily basis. All of the materials pumped from the producing wells could be either reinjected (mainly CO_2 and water) or transported off-site for other uses, such as oil and gas products or sulfur.

AUTHORIZING ACTIONS

FEDERAL

Bureau of Land Management

The BLM has the responsibility for authorizing the following actions and preparation of environmental assessments where necessary. The BLM will coordinate the preparation of right-of-way stipulations by federal agencies to ensure consistency where possible.

1. Issuance of a grant of right-of-way for construction and operation of a main CO_2 pipeline for 478 miles from southwestern Colorado to Denver City, Texas. Issuance of the right-of-way would be made under Title V of the Federal Land Policy and Management Act (FLPMA) of 1976, as defined in 43 CFR 2800. The grants of right-of-way would be issued from the BLM New Mexico State Office and BLM Colorado State Office as appropriate.

2. Authorization of facilities ancillary to the main pipeline, such as 126 miles of gathering lines, 13 central facilities, an origin station, and electric transmission facilities will be under the terms of the mineral lease or by right-of-way grant. Right-of-way grants would be issued by the BLM New Mexico State Office at Santa Fe or the BLM Colorado State Office at Denver as appropriate. Right-of-way grants would be made pursuant to Title V of the Federal Land Policy and Management Act of 1976 (90 Stat. 2776, 43 U.S.C.A. Section 1701, *et seq*. (1799 Supp.)), and regulations under 43 CFR 2800.

3. Issuance of grants rights-of-way for 159 miles of access road. These rights-of-way would be issued as Tramroads under Part 2810, 43 CFR. These grants would be issued by the BLM Colorado State Office at Denver.

4. Issuance of grants of right-of-way for nine communications sites to be located on public lands in Colorado and New Mexico. Issuance of these grants would be made under 43 CFR 2860. These grants would be made separate from the right-of-way for the pipeline and ancillary facilities. These rights-of-way would be made by the BLM New Mexico State Office and the BLM Colorado State Office as appropriate.

5. Issuance of an undetermined number of Noncompetitive (Negotiated) Sales of Mineral Material (Commercial fill, sand and gravel, and other surfacing or construction material of common variety) under 43 CFR 3611. These would be issued from the Montrose Office, Albuquerque Office, or Roswell Office of the BLM.

6. Issuance of approximately 37 temporary use permits for temporary work and storage sites at major drainage crossings, highway and railroad crossings, and other utility crossings. These would be issued under Part 43 CFR 2920, "Special Land Use Permits". The permits would be issued from the Montrose Office, Albuquerque Office, or the Roswell Office of the BLM.

The grants of right-of-way and other permits issued by the BLM would include general and specific stipulations. These stipulations would include the following general measures:

1. The applicant shall conduct all activities associated with the project in a manner that will avoid or minimize degradation of air, land, and water quality. In the construction, operation, maintenance, and termination of the project, the applicant shall perform its activities in accordance with applicable air and water quality standards, related facility siting standards, and related plans of implementation, including but not limited to standards adopted pursuant to the Clean Air Act, as amended (42 U.S.C. 1857) and the Federal Water Pollution Control Act, as amended (33 U.S.C. 1321).

2. The applicant will be required to undertake every reasonable means to minimize erosion and soil damage in connection with any construction, rehabilitation, or maintenance operations including (but not limited to) construction of water bars, cross ditches, or other structures as needed.

3. Vehicular access travel shall be confined to the access roads shown on the construction plan. Access roads to be retained for operation and maintenance of the CO_2 project will be clearly identified. Cross-country and off-road vehicular travel will not be allowed. Access ways and staging areas denuded of vegetation during construction will have suitable buffer strips between them and perennial streams. Buffer strip widths will be determined based on the method derived by Packer and Christiansen in "Guide for Controlling Sediment from Logging Roads."

4. Roads required for access by the applicant will be maintained and/or rehabilitated as necessary if damaged beyond normal wear and tear by the applicant's vehicles.

5. Completed construction areas and roads no longer required for use will be returned to as near original condition as possible at the discretion of the Authorized Officer.

6. At the discretion of the Authorized Officer or landowner, soils removed during construction will be stockpiled for use in post-construction rehabilitation.

7. Revegetation will be done on all disturbed areas as directed by the Authorized Officer or landowner. The seed mix or plant species will be provided by the applicant and planted in accordance with techniques prescribed by landowner or managing agency.

8. Only the portion of the rights-of-way needed for construction will be cleared.

9. The applicant shall protect the scenic aesthetic values of the area and the adjacent land as much as possible during construction, operation, and maintenance of the improvements.

10. Ground vehicular equipment shall not be operated if soil or weather conditions result in rutting, flowing, or other displacement of soils. Any exception to this requirement must be approved in advance by the Authorized Officer in charge.

11. All above ground improvements and barricades shall be nonreflective. If a safety color is required, only the minimal area shall be that color. When a safety color is not required, the color used shall be chosen to blend with the natural background for that location.

12. Chemical materials may not be used to control undesirable woody and herbaceous vegetation aquatic plants, insects, rodents, trash, fish, etc., without the prior written approval of each land management agency. A report of planned use of pesticides will be submitted annually by the due date established by the land management agency.

13. If a natural barrier used for livestock control is broken during construction, the applicant will adequately fence the area to prevent drift of livestock.

14. To prevent slackening of fence wire, the applicant will brace and tie off each existing fence to be crossed before cutting. The opening will be protected as necessary during construction to prevent the escape of livestock. Upon completion of construction, the applicant will reconstruct the fence to its original condition. The Applicant will install a cattle guard with an adjacent 12 ft gate in any fence where a road is to be regularly traveled.

15. No gates or cattleguards on established roads on public land will be locked or closed by the applicant.

16. Garbage, trash, and other refuse will be disposed of in an authorized disposal site or landfill. Engine oil changed on the right-of-way will be caught in suitable containers and disposed of as trash; no spillage of fuel, oil, or other hydrocarbons is permitted. If such a spill accidently occurs, the contaminated soil is to be excavated.

17. Prior to initiating any ground disturbing activities related to this project, The applicant will: conduct a cultural (archaeological and historical) resources inventory (Class III) of the total area of ground disturbance regardless of ownership; evaluate all of the sites, buildings, districts and objects identified in the inventory using the National Register of Historic Places criteria; and carry out the cultural resource protection measures directed by the Authorized Officer with 36 CFR 800.

18. The inventory and the evaluation shall be completed and the results, in the form of an inventory report, shall be submitted to the Authorized Officer at least 30 days in advance of any project related surface disturbance. The inventory report shall detail the results of the inventory and evaluation, and shall make recommendations for cultural resource protection measures.

19. Cultural resource protection measures may include, but need not be limited to signing, patrolling, fencing, erosion control, preservation, avoidance by relocation of the pipeline, salvage, and other physical or administrative measures. Where prudent and feasible, avoidance shall be the preferred means of protection.

20. During project construction the applicant shall have a Project Archaeologist to insure compliance with avoidance stipulations by construction activities, vehicles, and other equipment and to inspect the areas of surface disturbance for subsurface cultural materials. If such materials are discovered, the applicant must report the find to the Authorized Officer, provide an on-the-ground opinion regarding the protection measures to be undertaken, and leave the find intact until clearance to proceed is granted by the Authorized Officer. The applicant shall fund all protection measures undertaken, and shall provide for the salvage of artifacts unavoidably disturbed by construction.

21. All archeologists and historians who provide inventory services, prepare reports, perform mitigation, or monitor construction activities must meet the standards in 36 CFR 61.5 and must be approved by the Authorized Officer. All salvage work on federal lands will be authorized under

an antiquities permit. Salvage work on other lands will be conducted under appropriate state permits.

22. Landowners, permittees, and other regular users of public lands in the right-of-way will be notified in advance of construction activities that may affect their business or operations. This would include signing of any temporary road closures in advance of construction. Ranchers would be advised of any fence openings, disturbances to range improvements, or other range-use related structures in advance of construction.

Bureau of Indian Affairs

Issuance of grants of right-of-way for construction and operation of a main CO_2 pipeline through the following Indian tribal lands:

- Navajo Indian Trust Lands, 36.5 miles
- Southern Ute Indian Reservation, 5.9 miles
- Zia Indian Reservation, 13.9 miles
- Santa Ana Pueblo Indian Reservation, 5.9 miles

The Bureau of Indian Affairs (BIA) exercises the Secretary of the Interior's trust responsibility in review and approval of agreements between the Indian tribes and private companies concerning development of Indian land. Secretarial approvals of action on Indian lands, in his trust capacity, are independent of right-of-way approvals on public lands. Granting the proposed rights-of-way and approving any of the related developments discussed in this ES does not commit the Secretary of the Interior to any decision regarding Indian lands within or adjacent to the proposal.

The rights-of-way would be approved subject to standard requirements for duration of the grant, right-of-way widths, fees or costs, and bonding to secure obligations, imposed by the terms and conditions of the right-of-way grant. Rights-of-way across Indian Trust lands administered on Indian Tribal fee lands would be negotiated with the respective Indian tribes.

Authority for issuance of these rights-of-way would rest with the Superintendent of the Indian Agency or the Superintendent in charge of the reservation on which the lands involved are situated, in accordance with 25 CFR 161.

U.S. Army Corps of Engineers

This project meets the conditions of a nationwide Section 404 permit.

United States Geological Survey

The USGS has the responsibility for preparation of an environmental assessment as part of the approval process for drilling operations on public lands and Indian tribal lands. In addition, the USGS approves the following actions.

- Drilling permits (APDs)
- Sundry notices of reports on wells
- Produced water disposal
- Abandoned wells
- Unit agreements and unit actions

The USGS also carries out inspections for compliance with the oil and gas operating regulations in accordance with 30 CFR 221.

U.S. Fish and Wildlife Service

Clearance related to Section 7 consultation as required by the Endangered Species Act of 1973.

U.S. Forest Service

The San Juan National Forest would issue rights-of-way for the access roads and gathering lines under Title V of FLPMA. The study area does not contain any lands being considered under USFS Roadless and Undeveloped Area Evaluation II (RARE II) program. Access roads are covered by 36 CFR 221. The exact length of right-of-way in each case would depend on the final determination of the number of wells required. The Cibola National Forest would issue rights-of-way for approximately 5 miles of the main CO_2 pipeline. An undetermined number of non-competitive sales of mineral materials would be made from the USFS. The grants of right-of-way issued by the USFS would include general and specific stipulations. These stipulations would include the following general measures:

1. The applicant will prepare a project construction plan, fire plan, and a landscape plan. These plans will be approved by the respective authorized officer or landowner prior to commencement of construction of the project.

    a. The construction plan will have, but not be limited to: the alignment of the pipe or transmission line, contract specifications, access roads, clearing of vegetation for trenching, pole setting, type of trench by area, cuts and fills, and any other activities related to construction of the project.

b. The fire plan will include, but not be limited to: channels of responsibility for fire prevention and suppression, attack procedures, tools, equipment, and manpower.

c. The landscape plan will show, but not be limited to: (a) the display of the patterns and density reduction of the vegetation that will be used to reduce the "slot" effect that may be created by the pipeline or transmission line, (b) the species and methods of revegetation, and (c) a soil erosion control display. Also, the landscape plan will show the areas of slash disposal and type of slash disposal.

2. The applicant shall conduct all activities associated with the project in a manner that will avoid or minimize degradation of air, land, and water quality. In the construction, operation, maintenance and termination of the project, the applicant shall perform its activities in accordance with applicable air and water quality standards, related facility siting standards, and related plans of implementation, including but not limited to standards adopted pursuant to the Clean Air Act, as amended (42 U.S.C. 1857) and the Federal Water Pollution Control Act, as amended (33 U.S.C. 1321).

3. The applicant will be required to undertake every reasonable means to minimize erosion and soil damage in connection with any construction, rehabilitation, or maintenance operations including (but not limited to) construction of water bars, cross ditches and other structures as needed.

4. Vehicular travel shall be confined to the access roads shown on the construction plan. Access roads to be retained for operation and maintenance of the CO_2 project will be clearly identified. Cross-country and off-road vehicular travel will not be allowed. Access ways and staging areas denuded of vegetation during construction will have suitable buffer strips between them and perennial streams. Buffer strip widths will be determined based on the method derived by Packer and Christiansen in "Guide for Controlling Sediment from Logging Roads."

5. Roads required for access by the applicant will be maintained and/or rehabilitated as necessary if damaged by their vehicles, other than normal wear and tear.

6. Completed construction areas and roads no longer required for use will be returned to as near original condition as possible at the discretion of the Authorized Officer.

7. At the discretion of the Authorized Officer, dust control measures will be required within 1 mile of residences or other

populated areas. Watering of roads will be required prior to and during periods of heavy vehicular traffic in areas of fine textured soils.

8. At the discretion of the Authorized Officer or landowner, soils removed during construction will be stockpiled for use in post-construction rehabilitation.

9. Revegetation will be conducted on all disturbed areas as directed by the Authorized Officer or landowner. The seed mix or plant species will be provided by the applicant and planted in accordance with techniques prescribed by landowner or managing agency.

10. Only those portions of the rights-of-way needed for construction will be cleared.

11. The applicant shall protect the scenic aesthetic values of the area and the adjacent land, as far as possible during construction, operation, and maintenance of the improvements.

12. Ground vehicular equipment shall not be operated if soil or weather conditions result in rutting, flowing, or other displacement of soils. Any exception to this requirement must be approved in advance by the Authorized Officer in charge.

13. All above ground improvements and barricades shall be non-reflective. If a safety color is required, only the minimal area shall be that color.

14. Chemical materials may not be used to control undesirable woody and herbaceous vegetation aquatic plants, insects, rodents, trash, fish, etc., without the prior written approval of each land management agency. A report of planned use of pesticides will be submitted annually by the due date established by the land management agency. The report will cover a 12-month period of planned use beginning 3 months after the reporting date. Information essential for review will be provided in the form specified. Exceptions to this schedule may be allowed only when unexpected outbreaks of pests require control measures which were not anticipated at the time the annual report was submitted.

    Only those materials registered by the U.S. Department of Agriculture for the specific purpose planned will be considered for use on these lands. Label instructions will be strictly followed in the preparation and application of pesticides and disposal of excess materials and containers.

Department of Transportation

The Department of Transportation would be informed as to the nature, size, and length of the pipeline as outlined in 49 CFR 195.

Federal Communications Commission

The FCC would issue an operating permit for the communications system used to operate the pipeline. Authority for the permit and procedure by which it would be issued would be under 47 CFR 1.

Advisory Council on Historic Preservation

Section 106 of the Historic Preservation Act of 1966 (as amended) requires that the President's Advisory Council on Historic Preservation have an opportunity to comment on any undertaking which affects cultural resources on or eligible for the National Register of Historic Places in order to protect those resources. Executive Order 11593 (Protection and Enhancement of the Cultural Environment) mandates that all Executive Branch agencies, bureaus, and offices (1) compile an inventory of the cultural resource for which they are trustee; (2) nominate all eligible government properties to the National Register of Historic Places; (3) preserve and protect their cultural resources; (4) insure that agency activities contribute to the preservation and protection of non-federally owned cultural resources. The Advisory Council implements these regulations through the process outlined in 36 CFR 800 (Protection of Historic and Cultural Properties).

In order to protect cultural resources that may be affected by construction of the proposed project and to comply with the regulations discussed above, the applicant will conduct appropriate studies and will provide information necessary to complete the preliminary case report requirements (see 36 CFR 800.13(b)), as advised and assisted by the lead agency and State Historic Preservation Officers (SHPO). Information in the preliminary case report will provide for an adequate review of the effect of the construction of proposed project on cultural resources that are in the area to be disturbed.

The following items are the primary steps in the 106 process that will be undertaken by the applicant:

1. Identify all presently known cultural resources within the area that may be affected.

2. Avoid, through project design, all presently known cultural resources.

3. After finalization of facility locations and rights-of-way and prior to construction conduct a cultural resource survey (BLM Class III) in all areas that will be disturbed

by project construction to locate presently unknown cultural resources. The lead agency and SHPO will be responsible for formal determination of National Register eligibility and nomination.

4. Cultural resources located during the cultural resource survey will be avoided when prudent and feasible and/or as directed by the lead agency.

5. If avoidance is not prudent or not feasible, undertake a site-specific data recovery plan to mitigate the effect after plan approval by the lead agency and SHPO. Site-specific data recovery plans will relate to applicable and approved research designs as well as detail methods appropriate to mitigation of effects at that site.

STATE

New Mexico

A permit for operation of the pipeline would be obtained from the State Land Office.

Permission to bore under highways would be obtained from the State Highway Department.

Texas

Regulatory power rests with the Texas State Railroad Commission; permission would be obtained prior to construction.

INTERRELATIONSHIPS

EXISTING AND PROPOSED PROJECTS

Dolores Project

The major interrelationship of the proposed project would be with the Dolores Project. The major effect would be the presence of two sets of construction workers. The estimate of workforce requirements for the Dolores Project has changed since the publication of the Environmental Impact Statement (Bureau of Reclamation 1977). The present circumstances differ from the assumptions under which the analysis of the Dolores Project was made. The assumptions of full funding, no delays, and no controversy in the analysis proved invalid. The

project is now expected to require about half as many workers as originally predicted (Coulter 1979). The original estimate was for 340 people to be employed; half this number, or 170 people, equals the new estimate.

The total number of new people in the Cortez area that would be directly employed by the construction of the proposed CO_2 project would be 95 (see Chapter 3, Socioeconomics, CO_2 Well Field, Construction). The total of both the CO_2 project and the Dolores Project, therefore, would be 265 people.

Dolores River, Wild and Scenic

The National Wild and Scenic Rivers Act of 1968 created a system of wild, scenic and recreational rivers; designated the initial components of the system; and set forth procedures by which additional rivers could be added. Section 5(a) of the Act listed rivers to be studied for potential addition to the system. The Act was amended by P.L. 93-621 in January 1975. The Dolores River in Colorado was included in a study that was completed in November 1976. Of the portions of the river designated for study; the "Segment #3" - Main stem from West Boundary, Section 2., T. 38N., R. 16W., NMPM, below proposed McPhee Dam to 1 mile above Highway 90 bridge near Bedrock is of concern to the proposed action.

The McPhee Dam of the Dolores Project, authorized in 1968, was considered "In Place" for purposes of study during the consideration for inclusion in the system. The classification system has determined the segment from McPhee Dam to Bradfield bridge to be a "Recreational River Area". The segment below Bradfield Ranch bridge to 1 mile above Highway 90 bridge meets criteria as a "Scenic River area". An Environmental Impact Statement on the proposed Wild and Scenic River designation was prepared by the Bureau of Outdoor Recreation and the Forest Service in 1976. The action is pending Congressional approval.

OTHER PROPOSED PROJECTS

Several other projects are proposed for the Cortez area. These include a power plant proposed by Colorado Ute Electrical Association; and three irrigation projects - the McElmo Project, the San Miguel Project and the Animas La Plata Project. Published descriptions of these proposed projects are not yet in sufficient detail to determine interrelationships with the proposed CO_2 project. The Paradox Salinity Project and Dallas Project (an irrigation project north of Ridgway, Colorado) are far enough removed from the proposal as to have no interrelationships.

WILDERNESS STATUS

Colorado

Under the authority and direction of Section 603 of the Federal Land Management and Policy Act of 1976, the BLM in Colorado is presently

studying the public lands in the vicinity of the proposed action for roadless wilderness potential. The first roadless wilderness potential study areas are in the final stages of preparation; however, they are not available at the time of this draft. Maps and descriptions of these areas will be included in the final ES.

Any areas of conflict between the roadless wilderness study areas and the rights-of-way for the proposed area will be resolved through additional alternatives. If warranted, Supplemental Environmental Assessments will be prepared for Conflict Resolution of Roadless Wilderness.

New Mexico

The Federal Land Policy and Management Act of 1976 (FLPMA) directed the BLM to study public lands to assess their wilderness potential. The BLM wilderness review process has three phases: inventory, study, and reporting.

BLM has inventoried the roadless areas traversed by the pipeline in New Mexico and have recommended they be dropped from further wilderness consideration because they lack wilderness characteristics. The recommendation was released by the New Mexico State Director of the BLM on March 12, 1979. This release initiated a 90-day public comment period to end on June 9. If there is public concensus on this recommendation all roadless areas traversed by the pipeline will be "officially" dropped from further wilderness considerations. If the public disagrees then BLM will conduct an intensive wilderness inventory on the specific roadless areas with which there is disagreement as to the presence or absence of wilderness characteristics.

Any areas of conflict between the roadless wilderness study areas and the rights-of-way would be resolved in the same manner as discussed above for Colorado.

Other Land Use Plans

The eastern portion of the Doe Canyon Field would be part of National Forest lands covered by the Dolores District multiple use plan completed in February, 1970. This plan will be updated under provisions of the National Forest Management Act of 1976 in October, 1980.

The area surrounding the proposed CO_2 well fields has been included in a BLM planning unit as part of the Unit Resource Analysis - Management Frame Work Plan (URA-MFP) completed in 1971. The entire area will be updated in 1983-84.

The public lands surrounding the proposed pipeline have been included in numerous planning units and URA-MFPs in New Mexico, of varied completion dates. As these MFPs predate the Federal Land Management and Policy Act of 1976, there are no recommended utility corridors. All MFPs are scheduled for updating.

CHAPTER 2

DESCRIPTION OF ENVIRONMENT

EXISTING ENVIRONMENT

CLIMATE

CO_2 WELL FIELD

The CO_2 well field in southwestern Colorado has a mild, semiarid continental climate. Large-scale meteorological influences in the project area are relatively weak. The climate from location to location varies with changes in latitude, elevation, and local topography.

Long-term meteorological data reported for Cortez, Colorado is considered to be representative of the CO_2 well field. In addition, five meteorological stations and one air quality station were established in the CO_2 well field to gather site-specific data on wind direction and speed, temperature, dew point, precipitation, relative humidity, total suspended particulates (TSP), and SO_2 (Table 2-1). This network of recording stations was designed to take into account local topography and elevation changes (Map 2-1).

Temperatures in the area vary with season, location, and elevation. The mean annual temperature is about 49°F. The warmest month is July, with an average temperature of 72°F. The coldest month is January, with an average temperature of 27°F.

The frost-free season in the area averages approximately 120 days. The first freeze occurs about September 30 and the last freeze occurs in the spring, about May 30.

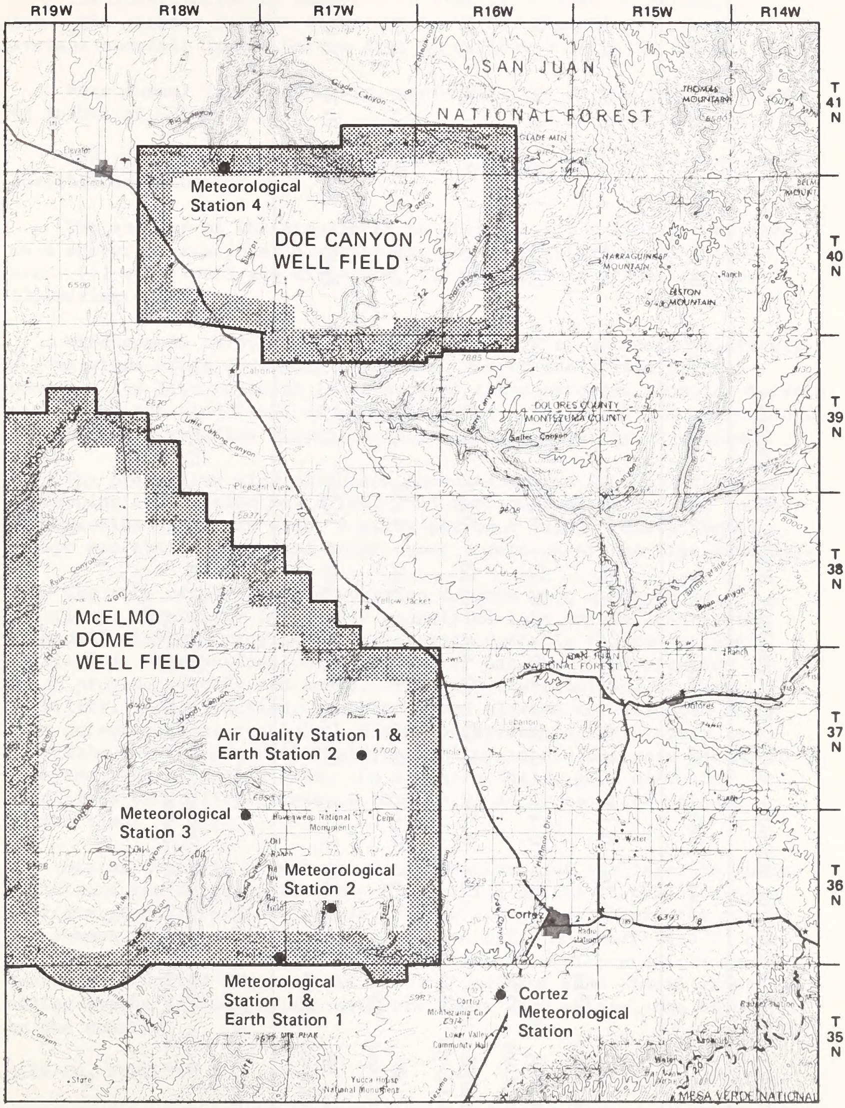
The annual average relative humidity is approximately 56 percent. Due to cooler temperatures, relative humidities are usually greater during winter and in the early morning hours.

Precipitation within the project area varies according to topography and elevation, with higher elevations receiving more rainfall. The normal annual precipitation for Cortez near the CO_2 well field is 12.9 inches (Table 2-2). The months with the most rainfall are July and August; many brief, though frequently severe, thunderstorms occur during this period. The CO_2 well field area averages about 35 days per year with thunderstorms, and though large-scale floods are uncommon these storms often cause local flash-flooding.

Table 2-1. CO_2 WELL FIELD METEOROLOGY AND AIR QUALITY MONITORING PROGRAM

Site	Location	Elevation (ft MSL*)	Equipment	Instrument Height	Parameter Measured	Period of Record Start	Period of Record Termination
Met Station #1	McElmo Moqui Creek	5675	Electronic Weather Station	10 meters above ground	Wind direction, wind speed, temperature, dew point, precipitation, snow depth (at one meter)	4/9/77	Continuing
Met Station #2	Goodman Canyon	5775	Electronic Weather Station	10 meters above ground	Wind direction, wind speed, temperature, precipitation (at one meter)	4/8/77	Continuing
Met Station #3	Sand Canyon Plateau	6810	Mechanical Weather Station	10 meters above ground	Wind direction, wind speed, temperature, relative humidity	4/9/77	Continuing
Met Station #4	Dove Creek Doe Canyon	7410	Mechanical Weather Station	10 meters above ground	Wind direction wind speed, temperature	4/9/77	Continuing
Air Quality Station #1	Colorado State U., Agronomy Station	6615	III-Vol Sampler,	10 feet	TSP	5/13/77	Continuing (every 8th day)
			RAC-3 Gas Sampler	10 feet	SO_2	6/9/77	Continuing (every 8th day)

*MSL = Mean Sea Level.



Map 2-1. CO_2 WELL FIELD METEOROLOGICAL AND AIR QUALITY MONITORING STATIONS

Table 2-2. PRECIPITATION NORMALS ALONG THE PROJECT ROUTE (in inches)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
CORTEZ, CO Elevation: 5914 ft	1.04	0.82	1.02	1.05	0.94	0.54	1.14	1.60	1.16	1.54	0.84	1.21	12.90
FARMINGTON, NM Elevation: 5502 ft	0.54	0.46	0.52	0.60	0.47	0.46	0.78	1.18	0.85	1.08	0.47	0.66	8.07
ALBUQUERQUE, NM Elevation: 5314 ft	0.30	0.39	0.47	0.48	0.53	0.50	1.39	1.34	0.77	0.79	0.29	0.52	7.77
CORONA, NM Elevation: 6500 ft	0.61	0.60	0.76	0.79	1.01	1.38	2.71	3.04	1.76	1.04	0.51	0.75	14.96
ROSWELL, NM Elevation: 3669 ft	0.40	0.37	0.47	0.48	1.00	1.24	1.71	1.48	1.47	1.22	0.29	0.47	10.61

T = trace (<0.01 inches).

Source: U.S. Department of Commerce 1964, 1969, 1973a, 1974, 1975.
U.S. Department of Commerce 1973b, 1973c.

The distribution of snowfall is similar to that of rainfall, i.e., the greater amounts occur at the higher elevations. Yearly average snowfall in the Cortez area is estimated to be 41 inches.

Mean annual lake evaporation representative of the area is about 42 inches at Cortez.

The project area annually receives approximately 75 percent of the possible sunshine.

The ability of the atmosphere to disperse air pollutants depends on a number of atmospheric variables, the most important of which are: (1) wind speed and direction, (2) atmospheric stability, and (3) mixing depth.

Wind speeds throughout the area are moderate, although relatively strong winds often accompany occasional winter and spring frontal passages and tend to occur in advance of thunderstorms. Complex terrain may affect the wind field by channeling the flow in valleys and canyons, causing the prevailing direction to parallel the valley or canyon.

The prevailing wind direction measured in the CO_2 well field by meteorological station No. 3 (Map 2-1) was southwesterly. The annual average wind speed was about 8 miles per hour (mph). Winds above 19 mph are not uncommon and occur about 3 percent of the time annually.

The rate of pollutant dispersion depends upon atmospheric stability. Stability is usually classified into several categories (Pasquill classes) ranging from extremely unstable (A) to extremely stable (G). The National Climatic Center has developed programs which provide monthly and annual frequency distributions of Pasquill stability, wind direction, and wind speed classes for selected long-term meteorological stations. Since no representative program is available for the CO_2 well field, stability conditions were estimated from the year of onsite data. On a yearly basis, good diffusion conditions (stability classes A through D) occur about 60 percent of the time.

Mixing depth is a measure of the thickness of the layer in which pollutants can disperse freely. High mixing depths in the afternoon indicate good dispersion. Mixing depths are generally greater after the common nocturnal inversion has burned off. Holzworth (1972) has studied mixing depths for 62 National Weather Service stations in the continental United States. His results indicate that annual afternoon mixing depths in the project area are about 2700 meters, the highest in the country.

MAIN CO_2 PIPELINE

The area crossed by the proposed main CO_2 pipeline route (parts of Colorado, New Mexico, and West Texas) has a mild, arid climate. Mean annual temperatures range from about 49°F near the pipeline

origin to about 62°F near the terminus in the Wasson Oil Field. The warmest month for all areas is July, when average temperatures vary between 72°F near the origin and 80°F near the terminus. The frost-free season along the route averages 120 to 210 days. The first freezing temperatures occur around October and the last around April or May. The coldest month is January, when temperatures average between 27°F and 41°F.

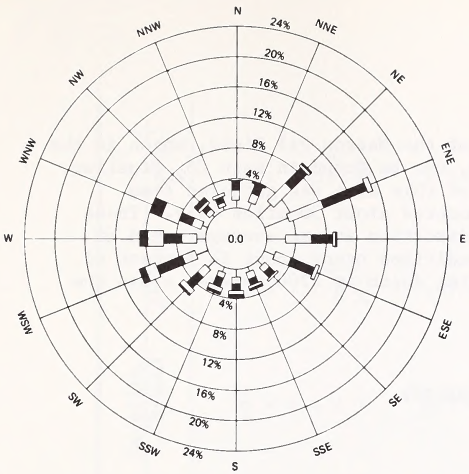
Annual average relative humidities along the pipeline route are about 56 percent at Cortez, Colorado; 42 percent at Albuquerque, New Mexico; and 56 percent at Denver City, Texas. The seasonal and diurnal variations are similar to those in the CO_2 well field area.

Precipitation along the route is greater at higher elevations. Normal annual precipitation for selected stations along the proposed pipeline range from 7.7 inches near Albuquerque to 14.96 inches near Corona (Table 2-2). The highest normal monthly precipitation occurs during July or August at each of these stations along the route. Thunderstorms are responsible for most of the rainfall in all areas except West Texas, where most of the precipitation occurs in May and is associated with frontal systems. Snowfall over the area will also increase as elevation increases. Annual average values range from 41 inches near the pipeline origin to 10 inches near the Wasson Oil Field terminus.

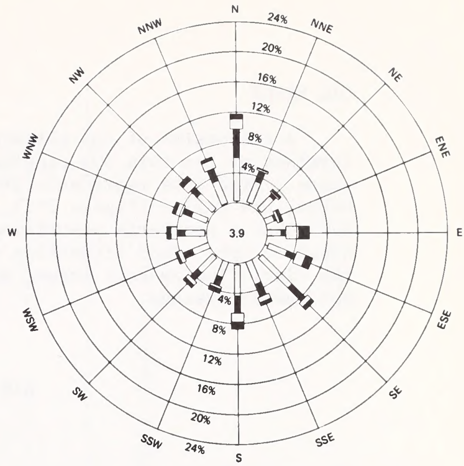
The pipeline route receives 75 percent of annual possible sunshine. Mean annual lake evaporation values range from 42 to 73 inches of water.

Wind speeds along the pipeline route are similar to those found in the CO_2 well field, although slightly stronger winds occur in the eastern plains of New Mexico and in West Texas. Wind direction is strongly affected by local topography and small-scale phenomena. This is demonstrated by the variation in prevailing directions for stations along the route (Figure 2-1). For example, the prevailing flow at Farmington is westerly, but a strong east-northeasterly component is also observed, possibly due to cold air drainage downslope during the night from the higher terrain to the east. During the day, as the surface becomes heated and the air moves upslope, the flow returns to westerly. These mountain-valley breezes are a common feature in rugged terrain. Winds above 18 mph occur commonly, about 15 percent of the time annually.

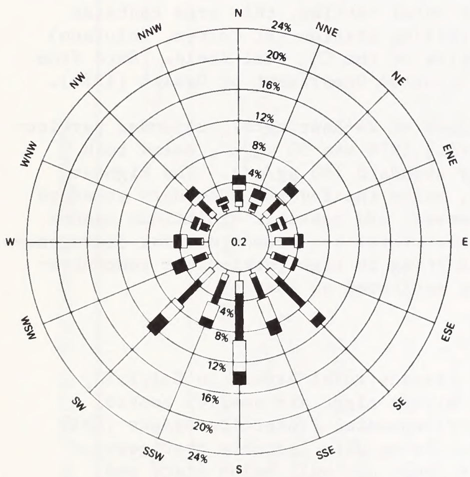
The diffusion characteristics along the route are similar to those in the vicinity of the CO_2 well field. Good dispersion conditions occur 60 to 65 percent of the time, according to National Climatic Center program results. Dispersion conditions vary seasonally; good conditions occur 78 percent of the time in July as compared with 55 percent in December.



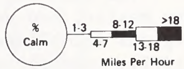
FARMINGTON, NEW MEXICO
Period of Record: January 1954 - December 1959



ALBUQUERQUE, NEW MEXICO
Period of Record: 1948 - 1968



HOBBS, NEW MEXICO
Period of Record: January 1949 - December 1954



Source: United States Department of Commerce 1973

Figure 2-1. ANNUAL WIND ROSES, NEW MEXICO

OIL FIELD

A discussion of the climate of the Wasson Oil Field, which is the terminus of the main CO_2 pipeline, can be found in Main CO_2 Pipeline, above. Wind data representative of this area was gathered from Hobbs, New Mexico (Figure 2-1), located about 30 miles away. These data show a southerly prevailing direction and an average speed of about 10 mph. Good dispersion conditions occur about 68 percent of the time. The average annual mixing depth is 2200 meters, above the nationwide average.

AIR QUALITY

CO_2 WELL FIELD

The CO_2 well field in southwestern Colorado lies in a rural area that is believed to be in attainment of national primary and secondary standards (Table 2-3). Due to its rural setting, this area contains only one official air quality monitoring station (at Cortez, Colorado) that may be considered representative of the CO_2 well field. Data from this site are available from the Colorado Department of Health (1976).

The average of 24 concentrations of 24-hour total suspended particulates (TSP) measured at Cortez during 1976 was 50 $\mu g/m^3$, below both the Colorado and federal secondary standard (60 $\mu g/m^3$). The highest 24-hour measurement was 125 $\mu g/m^3$, below the federal secondary standard (150 $\mu g/m^3$). Data are sparse, however, and possible violations cannot be discounted. Strong winds and duststorms are common natural occurrences in the southwest desert areas, resulting in high particulate concentrations. No gaseous pollutants were monitored at Cortez.

MAIN CO_2 PIPELINE

The main CO_2 pipeline, which crosses rural areas, in Colorado, New Mexico, and West Texas, falls within eight air quality control regions established by the U.S. Environmental Protection Agency (EPA) (1972). Available air quality monitoring data indicate that gaseous pollutant concentrations along the route are well below state and federal standards, but frequently exceed particulate standards. These data were measured at Farmington, Albuquerque, Roswell, and Hobbs; New Mexico (New Mexico Environmental Improvement Agency 1975).

Annual TSP concentrations range from 45 $\mu g/m^3$ at Hobbs (below the federal standard of 60 $\mu g/m^3$ and the New Mexico standard of 75 $\mu g/m^3$) to 160 $\mu g/m^3$ at Farmington. Background concentrations of TSP due to natural occurrences are expected to be high along the proposed pipeline route as in the CO_2 well field.

Table 2-3. FEDERAL AMBIENT AIR QUALITY STANDARDS

Standard	Duration: 1-hour	3-hour	8-hour	24-hour	Annual
PRIMARY (intended to protect public health)					
Carbon monoxide ($\mu g/m^3$)	40^b	-	10^b	-	-
Photochemical oxidants ($\mu g/m^3$)	160^b	-	-	-	-
Nonmethane hydrocarbons ($\mu g/m^3$)[a]	-	160^b	-	-	-
Nitrogen dioxide ($\mu g/m^3$)	-	-	-	-	100
Suspended particulates ($\mu g/m^3$)	-	-	-	260^b	75^c
Sulfur dioxide ($\mu g/m^3$)	-	-	-	365^b	80
SECONDARY (intended to protect public welfare)					
Carbon monoxide ($\mu g/m^3$)	40^b	-	10^b	-	-
Photochemical oxidants ($\mu g/m^3$)	160^b	-	-	-	-
Nonmethane hydrocarbons ($\mu g/m^3$)[a]	-	160^b	-	-	-
Nitrogen dioxide ($\mu g/m^3$)	-	-	-	-	100
Suspended particulates ($\mu g/m^3$)	-	-	-	150^b	$60^{c,d}$
Sulfur dioxide ($\mu g/m^3$)	-	1300^b	-	-	-

[a] 6 to 9 a.m., to be used as a guide in devising plans to achieve oxidant standards.
[b] Not to be exceeded more than once per year.
[c] Annual geometric means.
[d] To be used as a guide in achieving the 24-hour standard.
Source: U.S. Environmental Protection Agency 1976.

Annual average SO_2 concentrations measured during 1975 and 1976 ranged from near zero at Hobbs, New Mexico to 0.008 parts per million (ppm) at Farmington, New Mexico. These values are well below the federal standard (0.03 ppm) and the New Mexico state standard (0.01 ppm).

Ambient levels of NO_x monitored during 1975 and 1976 were below federal and state standards. The highest reported value was 0.0242 ppm (Farmington, New Mexico), while the lowest was 0.008 ppm (Hobbs, New Mexico). The federal annual nitrogen dioxide (NO_2) standard is 0.05 ppm.

OIL FIELD

Air quality data that can be considered representative of the Wasson Oil Field were measured at Hobbs, New Mexico. These data are presented in Main CO_2 Pipeline, above.

GEOLOGIC SETTING AND TOPOGRAPHY

The proposed CO_2 well field, main CO_2 pipeline, and oil field either traverse or are located in three physiographic provinces: (1) the Colorado Plateau, (2) Basin and Range, and (3) the Great Plains (Hunt 1974). The CO_2 well field lies near the eastern boundary of the Colorado Plateau in southwestern Colorado.

CO_2 WELL FIELD

<u>Topography and Stratigraphy</u>

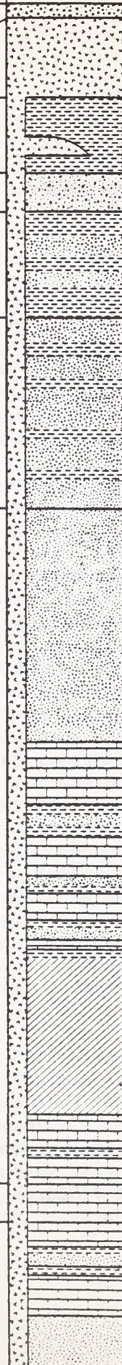
Topography in the CO_2 well field is dominated by mesas which have been deeply incised by local drainage and through-going streams such as the Dolores River and McElmo Creek. The mesa tops range from approximately 6500 to 8400 feet in elevation. Local relief around the mesas and steep-walled canyons may be as high as 1500 feet.

The rocks exposed at the surface in the proposed CO_2 well field range in age from the Upper Triassic to the Holocene. Exposed stratigraphy for the CO_2 well field is summarized in Table 2-4 along with a summary of subsurface stratigraphy.

The stratigraphy of the CO_2 well field is similar throughout and consists primarily of sequences of nearly flat-lying marine and nonmarine sandstones, siltstones, shales, and mudstones. Stratigraphy in the eastern portion of the McElmo Dome Field also includes the intrusive igneous rocks of Sleeping Ute Mountain.

Table 2-4. GENERALIZED STRATIGRAPHIC COLUMN OF CO_2 WELL FIELD

AGE	LITHOLOGY	FORMATION	DESCRIPTION
Quaternary (0 - 1.8 million years)		Surficial Deposits	Unconsolidated silt, sand, gravel, cobbles, and boulders; alluvium is potential aquifer; < 100 feet thick
Middle Tertiary - Late Cretaceous (25 - 65 million years)		Intrusive Igneous Rocks	Quartz diorite porphyry; intrusive igneous rocks of Sleeping Ute Mountain.
Late - Cretaceous (65 - 100 million years)		Mancos Shale	Soft, fissile, marine, clay shale; slope-forming; erodible; < 500 feet thick
Early Cretaceous (100 - 140 million years)		Dakota Sandstone and Burro Canyon Formation	Thick sandstone and conglomeratic sandstone beds; potential groundwater aquifer; < 250 feet thick.
Late Jurassic (140 - 160 million years)		Morrison Formation	Brushy Basin Member is bentonitic mudstone; erodible, and susceptible to slope wash and landslides. Other members are sandstone with interbedded shale and mudstone; < 700 feet thick
Late Jurassic - Permian (160 - 230 million years)		Junction Creek Sandstone, Summerville Formation, Entrada Sandstone, Carmel Formation, Navajo Sandstone, Kayenta Formation, Wingate Sandstone, Chinle Formation, Shinarump Sandstone, and Moenkopi Formation.	Fine- to coarse-grained sandstone and thin to irregularly bedded siltstone, shale, and fine-grained sandstone; forms alternating ledgy cliffs and low slopes. The Navajo Sandstone is a potential groundwater aquifer, total thickness approximately 1200 feet
Permian - Middle Pennsylvanian (230 - 300 million years)		Cutler Formation, Rico Formation, Hermosa Formation (with Paradox Salt Member)	Fine- to coarse-grained sandstone; interbedded limestone, sandstone and shale; limestone, dolomite and salt; total thickness approximately 4400 feet
Mississippian (310 - 345 million years)		Leadville Limestone	Massive limestone with thin interbedded shale; reservoir rock for CO_2; thickness approximately 250 feet
Devonian - Precambrian (345 - 570 million years)		Ouray Formation, Elbert Formation, Ophir Formation, and Tintic Sandstone	Limestone, dolomite, shale, siltstone and sandstone; total thickness approximately 1000 feet



The following discussion summarizes the CO_2 well field stratigraphy. The geology, including stratigraphy, in the CO_2 well field has been thoroughly discussed by Haynes et al. (1972), Finley (1951), Irwin (1966), O'Sullivan and Beikman (1963), Shoemaker and Holt (1973), Ekren and Houser (1965), and Steven et al. (1974).

Quaternary surficial deposits, the youngest of geologic units, cover much of the CO_2 well field and include stream-laid, landslide, and windblown deposits. Landslide debris is probably the most important deposit of Quaternary age. In the McElmo Dome Field, such deposits appear to be primarily associated with the bentonitic mudstone, Brushy Basin Member, of the Morrison Formation. Landslide debris in both the McElmo Dome and Doe Canyon areas is also associated with the clay shale of the Mancos Shale, when the shale occurs on steeper slopes. Large mapped landslides along the steep slopes of the Dolores River Canyon are notably absent, but numerous small landslide deposits probably exist along these slopes (Soule 1975). Stream-laid (alluvial) deposits along McElmo Creek, Dolores River, and other creeks are the principal groundwater bearing sediments in the CO_2 well field.

Igneous rocks of Cretaceous and Tertiary ages are exposed only in the vicinity of the McElmo Dome Field, where they are the predominant rocks of Sleeping Ute Mountain (immediately south of the field).

Mesozoic sedimentary rocks exposed in the CO_2 well field include Mancos Shale, Dakota Sandstone, Burro Canyon Formation, Morrison Formation, Junction Creek Sandstone, Summerville Formation, Entrada Sandstone, Carmel Formation, Navajo Sandstone, Kayenta Formation, Wingate Sandstone, and Chinle Formation. The Dakota Sandstone, Burro Canyon Formation, and Morrison Formation are significant Mesozoic geologic units to the environmental assessment. The Dakota Sandstone and Burro Canyon Formation are lithologically similar and consist of sandstone and conglomerate with some lenticular shale and mudstone. These units weather to form ledges and cliffs and are the principal mesa-capping formations in the CO_2 well field. Underlying the Dakota and Burro Canyon sandstones are the mudstones and sandstones of the Morrison Formation, which is generally confined to the canyons and slopes in the CO_2 well field. The mudstones, particularly the bentonitic mudstone of the Brushy Basin Member, are erodible, form low slopes below the Dakota Sandstone/Burro Canyon Formation, and are susceptible to landslides on the steeper slopes.

The stratigraphic units that occur in the subsurface underlying the lowest exposed Chinle Formation range in age from Lower Mesozoic to Precambrian. These units are sedimentary rocks that consist predominantly of marine and nonmarine siltstone, sandstone, limestone, and quartzite. The reservoir for the CO_2 occurs within the Mississippian Leadville Limestone (approximately 8000 to 9000 feet in depth) of the subsurface stratigraphic section in the CO_2 well field.

Structure

The geologic structure of the CO_2 well field is dominated by broad, low-dipping, plunging anticlines and synclines resulting in nearly flat-lying bedrock (dips generally less than 5°). This relatively simple structural pattern is complicated by faults that generally appear to be concentrated near bedrock folds and around the igneous intrusions (e.g., Sleeping Ute Mountain). The majority of the faults appear to be geologically old.

However, in the northeast portion of the McElmo Dome area the House Creek fault is mapped in fault contact with Quaternary windblown deposits which suggests Quaternary or geologically young movement. It is not clear, from the data presently available, whether the House Creek fault was active prior to or following the deposition of the Quaternary windblown deposits.

The Doe Canyon Field is crossed diagonally by the Dolores anticline. The axis of the anticline is cut by parallel faults that form the Glade Graben. These faults form distinct topographic lineaments which, together with Quaternary landslide deposits flanking the graben, suggest that the fault formed during the late Quaternary. In addition, the glacial deposits of Glade Mountain appear to have been displaced by one of the parallel faults of Glade Graben, suggesting Pleistocene to Holocene fault movement.

Another northwest-trending fault in the northwest portion of the Doe Canyon Field also exhibits geologic and topographic relationships which suggest Quaternary fault activity.

MAIN CO_2 PIPELINE

Topography and Stratigraphy

The following discussions summarize the geologic setting along the proposed main CO_2 pipeline. Detailed treatment of the geology along the pipeline route may be found in Haynes et al. (1972), Kelley (1971, 1972), Kelley and Northrop (1975), O'Sullivan and Beikman (1963), Steven et al. (1974), and Varnes (1976).

The main CO_2 pipeline would originate at the CO_2 well field and traverse its first 180 miles in the Colorado Plateau physiographic province of southwestern Colorado and northwestern New Mexico. Most of this distance is through the San Juan Basin, characterized by broad flats underlain by predominantly shale formations and separated by low ridges and mesas where more resistant strata crop out. Badlands topography is commonly well developed in the shales and local relief is low; the deep, steep-walled canyons found in the CO_2 well field are not common along this portion of the pipeline route.

The San Juan Basin contains approximately 10,000 feet of sedimentary rock younger than the Paleozoic (Hunt 1974). These sediments, consisting predominantly of nonmarine and marine sandstones and shales, become progressively younger toward the center of the basin near Nageezi, New Mexico.

For approximately the next 100 miles the proposed pipeline route traverses the Basin and Range province in central New Mexico. This area is characterized by geologically young faulting that results in structural valleys bounded by young mountain uplifts. Three typical landforms predominate:

- broad valleys of floodplains or dry lake beds
- alluvial fans rising from the valleys at the mountain bases
- rocky bordering mountains

Valley elevations along the route vary from 5500 to 6500 feet, while the mountains (which the route avoids) are from 3000 to 5000 feet higher.

The Basin and Range physiographic province is characterized by exposures of rocks ranging in age from the Precambrian to the Holocene. Precambrian rocks form the cores of the Sandia Mountains and Pedernal Hills uplifts. Paleozoic through Tertiary marine and nonmarine sedimentary rocks surround these uplifts. Late Tertiary through Quaternary stream and lake deposits are associated with the Rio Grande Rift and Estancia Basin.

For the final 200 miles, the proposed facilities would lie within the Great Plains physiographic province in southwestern New Mexico and West Texas. The Great Plains province is characterized by a broad eastward-sloping plain approximately 6000 feet in elevation at Encino, New Mexico and 3600 feet at Denver City, Texas. Little relief occurs in this broad, generally featureless plain except where it is cut by the Pecos River and locally where depressions and sink holes may occur.

The Great Plains province is typified by exposures of sedimentary rocks ranging in age from the late Paleozoic to the Holocene. Late Paleozoic gypsum, sandstone, dolomite, and limestone are common west of the Pecos River. The exposed bedrock from the Pecos River to Denver City consists predominantly of Pliocene silt, sand, and gravel with caliche developed near the ground surface. Surficial deposits of stream, dune, and lake origin are common and extensive on the broad surface of the Great Plains and cover large areas of bedrock.

Structure

Broad structural basins (e.g., the San Juan Basin) and upwarps dominate the geologic structure in the Colorado Plateau resulting in nearly flat-lying bedrock. Faulting appears to be concentrated near igneous intrusions and along fold axes, but becomes more frequent and extensive near the boundary of the Colorado Plateau and the Basin and

Range physiographic provinces, where they project to or cross the pipeline route. The regional data presently available are inadequate to determine the ages of faulting along the pipeline route within the Colorado Plateau province.

The geologic structure of the Basin and Range portion of the proposed pipeline is dominated by uplifts of Precambrian rock (Sandia Mountains) and faulting resulting in graben features such as the Rio Grande Rift. The faults bounding the Rio Grande Rift exhibit evidence of geologically young (Pleistocene and Holocene) activity (Woodward 1977, Woodward and DuChene 1975, and Kelley and Northrop 1975).

The structural geology of the Great Plains consists of nearly horizontal to slightly eastward-dipping sedimentary rocks overlying slightly deformed older rocks. Locally, the sedimentary rocks are intruded by igneous rocks. Faults occur near the Pecos River and also westward to the boundary with the Basin and Range province. Mapped fault relationships by Kelley (1971) suggest geologically young activity on some faults near the Pecos River. Karst topography, typified by sink holes and solution caverns, is common because of extensive deposits of limestone, dolomite, and other carbonate rocks present along this portion of the pipeline route.

PALEONTOLOGY

Much of the right-of-way of the proposed CO_2 pipeline is underlain by relatively barren rocks containing few or no fossils of significance. The northern portion of the CO_2 pipeline and CO_2 well field would overlie rock formations of significant paleontological interest.

Abundant dinosaur fossils are found in several of the formations beneath the CO_2 well field and the northern portion of the proposed pipeline right-of-way. Fossil mammal remains also exist in several of the formations. There would be no means of determining where a fossil might occur in the formation unless it was exposed at the surface or in outcrop. Descriptions of formations and fossils of the San Juan Basin and vicinity are found in BLM (1978), Loose (1978), Lucas (1977), Rigby and Lucas (1977), and Ekren and Houser (1965).

SEISMICITY OF CO_2 WELL FIELD AND PIPELINE

The following discussions summarize historic earthquake data in the CO_2 well field area and along the pipeline that may be significant to the environmental assessment.

The level of historic seismicity in the region of the proposed CO_2 well field is generally considered low in frequency occurrence and size of earthquakes when compared with other seismic regions, such as those in California. Although the seismicity is low, several significant

historic earthquakes have occurred in southwest Colorado. These earthquakes appear to have been concentrated to the east and northeast of the well field, with epicentral, felt intensities ranging from Modified Mercalli intensity (MM) IV to VII and magnitudes ranging from 4.6 to 5.5. The most significant earthquakes were associated with the January 22, 1966, 5.5-magnitude earthquake in Dulce, New Mexico and its 205 aftershocks (Simon 1969). In addition, a magnitude-5.5 earthquake was among a concentration of three earthquakes southeast of Montrose. The recent historic events include a 1941 MM V earthquake at Durango and a series of eight micro-earthquakes (ranging in magnitude from 2.0 to 4.0) recorded in the Four Corners area between 1966 and 1968 (Simon 1969).

An additional area of seismicity, northwestern New Mexico near Gallup, has had at least one historic MM VI earthquake. This general area recently (January 5, 1976) experienced a magnitude-5.0 earthquake that was strongly felt in southwest Colorado (Person 1976).

The level of historic seismicity along the pipeline route has been low to moderate. Historic earthquakes have been concentrated in the Rio Grande Rift between Albuquerque and Socorro (Coffman and von Hake 1975). Of nine strong earthquakes that occurred in the rift zone between 1869 and 1960, four had epicentral intensities of MM VIII, three between MM VI and VII, and two between MM V and VI (Coffman and von Hake 1975). Geomorphologic and geologic studies by Sanford et al. (1972) suggest that magnitudes of 7+ may have occurred in the Rio Grande Rift during the Quaternary and, based on these studies, the recurrence of a magnitude-6 event is considered to be 100 years.

An additional area of seismic activity is located in northeastern New Mexico, where 21 earthquakes were recorded between 1907 and 1971 (Northrop and Sanford 1972). The maximum epicentral intensity obtained was MM VI and the largest magnitude recorded was 4.8; however, this area generally lies to the north of the proposed pipeline route.

GEOLOGIC PROCESSES AND POTENTIAL GEOLOGIC HAZARDS

The geologic and tectonic processes in the CO_2 well field and along the pipeline may create potential geologic hazards that include:

- subsidence
- landsliding
- liquefaction
- earthquake shaking
- fault rupture

Subsidence could occur in the CO_2 well field and along the pipeline where Quaternary surficial deposits are present. The areas most susceptible to compaction of unconsolidated material would be alluviated stream valleys along the Dolores River, McElmo Creek, San Juan River,

Rio Grande, and Pecos River. These areas are small in extent when compared with the total area of the proposed project; in addition, the magnitude of this type of subsidence is generally relatively small. Subsidence could also occur in material overlying solution-prone or piping-prone bedrock. Known solution caverns and the area underlain by soluble carbonate rocks along the pipeline in southeastern New Mexico and West Texas could be susceptible to subsidence, as could the area in the San Juan Basin where erodible shale formations could be subject to piping. This type of subsidence is generally local in extent and significance.

Regional subsidence may be caused by fluid withdrawal of groundwater from a confined aquifer or by withdrawal of oil and/or gas. The Rio Grande Valley is a large groundwater basin along the pipeline; the CO_2 well field, San Juan Basin, and West Texas are areas of oil and/or gas production. Data are currently unavailable to describe the amount of subsidence, if any, presently occurring in the vicinity of the proposed project due to fluid withdrawal. In California, this sort of subsidence has reached nearly 30 feet in 40 years at Long Beach (Bolt et al. 1975) and nearly 30 feet in 30 years in the San Juan Valley (Poland et al. 1975).

Large landslides mapped in the well field and along the pipeline most likely occurred in the geologic past during a more humid climatic regime. Because of the present relatively arid climate, such large landslides are not expected to occur today. However, earthquake shaking may initiate landslides and rock falls, however, and undercutting of slopes during construction activities could create slope instability. Areas particularly susceptible to landslides include existing landslide deposits and areas where steep slopes (generally <35%) occur in conjunction with potentially unstable geologic formations (shales, mudstones, siltstones). The CO_2 well field facilities and the proposed pipeline route generally avoid areas with steep slopes and high relief.

Liquefaction and possible failure of unconsolidated materials could occur following seismic shaking caused by near or distant earthquakes. Stream valleys where the highest water tables occur together with unconsolidated material are most susceptible to this hazard. Data needed to delineate specific areas of potential liquefaction are currently unavailable although only a very few segments of the CO_2 well field and pipeline would cross areas susceptible to liquefaction.

Earthquake shaking is of concern since intense ground motion would adversely affect man-made structures. The degree of earthquake shaking is commonly defined by the measurement of the horizontal component of the acceleration of gravity.

Although the historic seismicity in the CO_2 well field region is of low frequency, the magnitudes of these past events have reached 5.5 (a moderate-sized earthquake). Based on the location of historic seismicity,

the CO_2 well field has probably experienced ground accelerations of less than 0.03 percentage of gravity (g); however, the potential for moderate-sized earthquakes in the region suggests that the CO_2 well field could experience accelerations greater than 0.03g. Further, the presence of probable late Quaternary faulting in the vicinity of the Doe Canyon Field indicates that future earthquakes could originate in at least that part of the CO_2 well field. The proximity of such potential earthquake sources could cause ground accelerations of greater than 0.03g in the CO_2 well field, depending upon distance to the causative faults. Although there appears to be a nominal potential for earthquake shaking in the field, the amount of shaking and the probability of its occurrence are yet uncertain.

The area within the Rio Grande Rift has had the largest historic earthquakes, as well as the greatest concentration of them along the pipeline. Based on the proximity of historic earthquakes and the presence of late Quaternary faulting in the Rio Grande Rift, it is likely that the proposed pipeline route near the Rio Grande Valley has experienced ground accelerations greater than 0.1g in the past and would likely experience them in the future.

SOILS

CO_2 WELL FIELD

Nine generalized soil associations (U.S. Soil Conservation Service [SCS] 1972a and 1972b) occur in the CO_2 well field:

- Cryoboralfs-Rock Outcrop
- Agriboralls-Haploborolls-Rock Outcrop
- Eutroboralfs-Rock Outcrop-Haploborolls
- Witt-Falfa-Potts
- Torrifluvents-Torriorthents
- Camborthids-Torriorthents-Haplargids
- Billings-Ravola-Christianburg
- Haplargids-Camborthids
- Torriorthents-Rock Outcrop

In general, the above associations directly or indirectly relate to the underlying geology. Pertinent estimated engineering characteristics of the soil associations in the CO_2 well field and related geologic units are based on data from SCS (1972a, 1972b). The most predominant associations in the vicinity of the McElmo Dome well field are the Witt-Falfa-Potts and the Camborthids-Torriorthents-Haplargids.

The former, which is widespread on the mesa tops, is associated with the productive, red eolian agricultural soil of the Cortez region. The latter occurs on the slopes below the mesas and is associated with the underlying mudstone, shale, and sandstone of the Morrison and older formations.

The predominant soil associations in the Doe Canyon well field include: (1) the Agriborolls-Haploborolls-Rock Outcrop association, which occurs mainly on the flat mesa tops east of the Dolores River; (2) the Witt-Falfa-Potts association, which appears on the mesa tops west of the Dolores River; and (3) the Torriorthents-Rock Outcrop association, which is generally confined to the steep slopes of the Dolores River Canyon.

Water and wind erosion are major factors contributing to soil losses in the CO_2 well field. Based on methods described in Appendix B, the estimated existing water-induced soil loss rate for the well field is 0.18 tons/acre/year. The rate of soil loss due to wind erosion is unquantifiable due to a lack of applicable methods.

MAIN CO_2 PIPELINE

The generalized soil associations that occur along the proposed main pipeline route and in the oil field are based on SCS soils maps. Soil and estimated engineering properties for each association are based on data from SCS (1972a, 1972b, 1972c) and other published sources.

Forty-five of approximately 90 soil associations in the vicinity would be crossed by the proposed main CO_2 pipeline (Table 2-5). These associations can be grouped into five major land classifications based on their potential for being developed as irrigable land (Table 2-6). According to these classifications, approximately 50 percent of the pipeline occurs in non-irrigable soil and 31 percent in potentially irrigable soil, while 19 percent is unmapped.

The existing water-induced soil loss rate along the pipeline route is estimated at 0.18 tons/acre/year. No estimates are available for the wind-induced soil loss rate.

Table 2-5. SOIL ASSOCIATIONS TRAVERSED BY PIPELINE AND LAND CLASS FOR IRRIGATION

Soil Association	Estimated Dominant Land Class(es)
Agiborolls-Haploborolls-Rock Outcrop	6
Eutroboralfs-Rock Outcrop-Haploborolls	6
Agriborolls-Haplaquolls	6
Witt-Falfa-Potts	1
Torrifluvents-Torriorthents	3
Camborthids-Torriorthents-Haplargids	4, 6
Hapargids-Torriorthents-Rock Outcrop	6
Persayo-Farb	6
Werlow-Fruitland-Turley	1, 2
Doak-Shiprock	2
Hilly-Gravelly Land	6
Badland-Rockland	6
Turley-Badland	2, 6
Penistaja-Pinavetes-Rockland	2, 3
Travessilla-Rockland	6
Del Rio-Silver	2, 3
Gila-Vinton-Glendale	1, 3
Christianburg-Navajo	3
Sheppard-Rough Broken Land	4, 6
Rough Broken Land-Embudo	6
Redun-Pena-Stony	2, 6
Persayo-Turley-Badland	6
Las Lucas-Litle-Persayo	4
Travessilla-Persayo-Rockland	6
Gaines	6
Witt-Harvey-Clovis	2
Harvey-Dean-Tapia	6
Laporte-Witt	6
Clovis-Scholle	2
Deama-Pastura-Manzano	6
Harvey-Pastura	3, 6
Harvey-Pastura-Witt-Tapia-Dean	3, 6
Penistaja-Rockland	6
Arno-Harkey	1, 3, 6
Reeves-Hollomun-Gypsumland	6
LaLande-Ima-Gypsumland	6
Redona-Canez-Douro	2
LaLande-Alama-Lacita	2

Table 2-5. (concluded)

Soil Association	Estimated Dominant Land Class(es)
Jalmar-Tivoli-Faskin	3, 6
Ector-Conger	6
Gypsumland	6
Kimbrough	6
Kimbrough-Lea-Stegall	6
Amarillo-Arvana	2, 6
Portales-Stegall-Lea	2

Note: See Table 2-6 for explanation of land classes.

Table 2-6. LAND CLASSIFICATION SPECIFICATIONS FOR PACIFIC SOUTHWEST BASIN IRRIGATION LAND CLASSES[a]

Land Characteristics	Class 1	Class 2	Class 3	Class 4	Non-irrigable Class 6
Soils					
Texture (Surface 12")[b]	LVFS-CL	LS-C Peat, Muck	MS-C	MS-C	All other lands not meeting criteria for arability
Moisture Retention (AWHC-48")[c]	>6.0"	4.5" 6.0"	3.0" 4.5"	2.5" 3.0"	
Effective Depth (inches)	>40[d]	30-40	20-30	10-20	
Salinity ($EC_e \times 10^3$ - equil.)	<4	4-8	8-12	12-16	
Sodic Conditions[e]					
Percent area affected	<5	5-15	15-25	25-35	
Severity of problem[f]	Slight	Moderate	Moderate	Moderate	
Permeability (in place - in./hr)	0.2-5.0	0.05-5.0	0.05-10.0	Any	
Permissible coarse fragments (% by vol.)					
Gravel	15	35	55	70	
Cobbles	5	10	15[g]	35[g]	
Rock Outcrops (distance apart in feet)	200	100	50	30	
Soil Erosion (for all classes)	Severely eroded soils will be downgraded one class. Less severely eroded soils may be downgraded one class, depending on other conditions.				
Topography (or land development items)[h]					
Stone for Removal (cubic yards per acre)	10	25	50	70	
Slope (percent)					
Moderately to severely erodible	<2	2-5	5-10	10-20	
Slightly erodible	<4	4-10	10-20	20-25	
Surface Leveling or Tree Removal (amount of cover)	Light	Medium	Medium heavy	Medium heavy	
Irrigation Method	Lands unsuited to gravity irrigation where land grading would permanently reduce soil fertility below arable limits or exceed permissible costs, or field pattern roo complex, may be considered for sprinkler. Land must meet other requirements for arability. Designate by "S" - example, 3-S.				
Drainage					
Soil Wetness (depth to water table during growing season with or without drainage)					
Loam or finer	>60"	40"-60"	20"-40"	10"-20"	
Sandy	>50"	30"-50"	20"-30"	10"-20"	
Surface Drainage	Good	Good	Restricted	Restricted	
Depth to Drainage Barrier (in feet)	>7	6-7	5-6	1.5-5	
Air Drainage[i]	No Problem	Minor	Restricted	Restricted	

[a]Specifications are representative of conditions after land is developed for irrigation. Each individual factor represents a minimum requirement and, unless all other factors are near optimum, two or more interacting deficiencies may result in land being placed in lower class or designated class 6 (non-irrigable).

[b]Finer textures may be required than those indicated for each class in areas subject to critical hot spells or wind; coarser textures may sometimes be permissible.

[c]In areas of very warm growing season, 3" may be required for class 4 and in cold areas as little as 5" may be permitted for class 1.

[d]Depth of 60" or more is required for class 1 where deep-rooted crops are important.

[e]More extensive and severe sodic problems may be tolerated in areas of wide crop adaptability.

[f]Severity of problem: slight - ESP less than 15% or less than 25% if dominated by nonswelling clays; moderate - ESP less than 20% or less than 30% if clay minerals favorable; severe - ESP less than 30% with certain soil minerals may range above 50% as measured by usual techniques.

[g]May range above 50% in subsoil for certain crops if surface soil is favorable.

[h]Special crop and management practices may justify exceeding the limits for stone removal or slope in class 4; irregularity of slope may necessitate downgrading of class unless deficiency is compensated for by possibility of sprinkler irrigation.

[i]Air drainage is a consideration mainly in areas adapted to fruit or to early or late vegetables.

Abbreviations:
LVFS - loamy very fine sand
LS - loamy sand
MS - medium sand
CL - clay loam
C - clay
AWHC - available water holding capacity
ESP - exchangeable sodium percentage

Source: Maker et al., 1974.

WATER RESOURCES

CO_2 WELL FIELD

Groundwater

Few, if any, data are available on the groundwater that underlies the proposed CO_2 well field. As a result, the following discussion was developed using information on the site's geology in conjunction with existing regional groundwater studies (Irwin 1966 and Cooley et al. 1969) for areas of similar geology.

In general, the availability of groundwater in this part of Colorado is limited (Pearl 1974). Few of the rock formations present are capable of yielding significant volumes of water; what water is produced is frequently of poor quality due to heavy mineralization. Within the proposed CO_2 well field, it is estimated that three specific formations contain the majority of the available groundwater: (1) stream alluvium, (2) the Dakota Sandstone of the Cretaceous period, and (3) the Navajo Sandstone of the Triassic and Jurassic periods (see Table 2-4 for their locations in the geologic column). The alluvium, though constituting a readily usable source of water, is found only in stream valleys and so provides only minor volumes of water (usually less than 10 gallons per minute [gpm]). While the thickness of the alluvium is not known, it is estimated to be less than 20 feet in most areas. The Dakota Sandstone is the principal aquifer in the vicinity of the proposed CO_2 well field and is generally located at or near the ground surface (the only major formation between it and the surface is the relatively impermeable Mancos Shale). The Dakota Sandstone yields small to moderate volumes of water to numerous stock and irrigation wells throughout the project area. Much of the water in the Dakota formation is under artesian pressure due to the confining layer of Mancos Shale overlying it. The Navajo Sandstone, while exposed in some areas, is more typically found at depths of 1000 feet or more. It produces small volumes of water to some stock and domestic wells, but is generally not tapped because of its depth.

Only limited data are available on the quality of groundwater in the proposed CO_2 well field, but it is probable that the water underlying the area is heavily mineralized, primarily from the presence of soluble material in the aquifers and in the adjacent rock formations. As a result, water samples in the area frequently show total dissolved solids (TDS) levels of more than 1000 parts per million (ppm). The dominant cation in all of these waters is bicarbonate, with a typical range from 50 to 500 ppm. Chloride and sulfate, the dominant anions, are frequently found in concentrations that exceed U.S. Environmental Protection Agency (EPA) drinking water criteria (1976). Nitrate and fluoride levels also exceed drinking water criteria on occasion, with the highest nitrate levels found in

alluvial waters (probably the result of decaying vegetable matter). Thus groundwater quality in the area can be considered generally poor, making these groundwaters unsuitable for some beneficial uses.

Surface Water

The proposed CO_2 well field lies within two major drainage basins. The eastern portion of the Doe Canyon Field is in the Dolores River Basin; the remainder of the CO_2 well field is in the San Juan River Basin.

Dolores River Basin. The Dolores River actually flows through the middle of the proposed Doe Canyon Field (i.e., well heads would be located in adjacent areas on both sides of the river). This river originates in the San Juan Mountains and much of its flow is derived from spring snowmelt, though summer thunderstorms occasionally contribute significant quantities of water. The variation in streamflow that results from these contributions is presented in Table 2-7, which shows the months of highest streamflow in each of the streams crossed by project facilities. In addition, an estimate of the flood frequency for all stream crossings is presented in Table 2-8.

The quality of water in the upper reaches of the Dolores River is high, but deterioration generally occurs as the water moves toward the Colorado River and dissolved solids and suspended sediment are input downstream. At the Dolores gaging station some 20 miles upstream from the CO_2 well field, the average monthly dissolved solids load ranges from 100 to 300 ppm. The average suspended sediment concentration at the Dolores station is somewhat higher at 245 ppm (Colorado Water Conservation Board and U.S. Department of Agriculture 1972).

Two major federal actions involving the Dolores River are in progress. The Dolores Project involves diversion of 105,200 acre-feet of water from the Dolores River near the city of Dolores to the San Juan River Basin and will include construction of the McPhee Reservoir on the Dolores River. The Dolores Wild and Scenic River Study recommends legislative action to include a 105-mile segment of the Dolores River in the National Wild and Scenic Rivers System. These two actions are discussed in Chapter 2, Wilderness Values and Recreational Resources.

San Juan River Basin. The portion of the well field within this drainage area is drained primarily by two minor tributaries of the San Juan River: McElmo Creek and Cross Canyon of Montezuma Creek. Both creeks have numerous tributaries but only the main stem of each has observable flows on a year-round basis. Since little is known about local flow characteristics, with the exception of McElmo Creek, the following analysis of the site's surface hydrology will concentrate on McElmo Creek.

Streamflow data from a gaging station on McElmo Creek near Cortez, Colorado, located just east of the proposed dry-CO_2 gathering pipeline,

Table 2-7. MONTHS OF HIGHEST STREAMFLOW

Gaging Station	Flood Flow Months
Dolores River at Dolores, CO	April, May, June, July
McElmo Creek near Cortez, CO	March, October
Mancos River near Towaoc, CO	March, May, June, July, August, October
La Plata River at state line	April , May, June, October
Animas River at Farmington, NM	May, June, July, August
San Juan River at Farmington, NM	May, June, July, August
Rio Grande River at San Felipe, NM	April, May, June, July, August
Pecos River near Acme, NM	March, June, July, August

Note: Flood flow month is defined as any month in which a daily flow rate exceeds the 75 percentile flow rate observed on an annual basis (i.e., the daily flow rate is equal to 75 percent or more of the maximum observed discharge for that year).

A review of the data also indicates that the low-flow period for these streams generally falls during the month of September and from November through February.

Source: U.S. Geological Survey 1970-1976.

Table 2-8. FLOOD-FREQUENCY DISCHARGE ESTIMATES

Route Location	Name of Stream Crossed	Drainage Area (square miles)	Flood-Frequency Discharge (cubic feet/second) 2-year	10-year	50-year	100-year
Doe Canyon dry-CO_2 line	Dolores River	820	4,990	9,690	14,400	16,500
McElmo Dome dry-CO_2 line	McElmo Creek	180	500	1,040	1,690	2,030
Main CO_2 line (MP 15)	Mancos River	92	260	700	1,390	1,830
Main CO_2 line (MP 34)	La Plata River	170	580	1,560	2,870	3,550
Main CO_2 line (MP 58)	Animas River	1,180	5,740	10,400	15,200	17,400
Main CO_2 line (MP 71)	San Juan River	3,470	9,020	18,900	29,500	34,600
Main CO_2 line (MP 203)	Rio Grande	16,400	7,930	17,700	27,800	32,400
Main CO_2 line (MP 378)	Pecos River	10,900	5,040	18,700	48,300	69,600

Source: U.S. Geological Survey 1979.

suggest that heavy flow occurs yearly for McElmo Creek during March and October (Table 2-7). These peak periods are typical of many unregulated streams in this region and reflect the effects of spring snowmelt and summer/fall thunderstorms. While little information is available on the floodplain or flooding potential of McElmo Creek, an estimate of the probable flood-frequency discharges for this stream at the proposed crossing point for a dry-CO_2 line is given in Table 2-8.

With the exception of some limited sampling of sediment loads, no water quality data are available for McElmo Creek. These sediment data indicate that McElmo Creek carries an annual sediment of roughly 60,000 tons (as measured at the Cortez monitoring station). This load, in conjunction with high concentrations of dissolved solids, tends to make all of McElmo Creek unsuitable for certain beneficial uses, particularly domestic water supply.

MAIN CO_2 PIPELINE

Groundwater

The main CO_2 pipeline crosses through four major drainage basins: (1) the San Juan River, (2) the Rio Grande, (3) the Pecos River, and (4) the Texas Gulf. Because the nature of the underlying groundwater varies, the following discussion addresses the groundwaters of each basin individually.

San Juan River. Groundwater is sparse in the San Juan River Basin. Few of the rock formations are capable of yielding large quantities of water; where available in quantity, it is usualy of poor quality.

In the basin's arid western portion, the depth to water is generally about 1000 feet or more, although it becomes more shallow to the east. The estimated amount of recoverable fresh groundwater (0-1000 mg/l TDS) in the San Juan Basin is only 2 million acre-feet.

Rio Grande. In contrast to the San Juan River Basin, the Rio Grande Basin has an abundant supply of groundwater; the deep alluvial troughs found along the Rio Grande store large quantities of groundwater. Depth of this groundwater varies but is generally shallow along the Rio Grande, averaging 10 feet in the area between Albuquerque and Belen. Estimates indicate that over 2.5 billion acre-feet of water with a TDS concentration of less than 1000 mg/l could be recovered from the basin.

Pecos River. Groundwater in the Pecos River Basin is subject to usage patterns similar to those of the Rio Grande Basin. The amount of water in the alluvium of the groundwater basin, which the pipeline crosses, is estimated to be about 1.5 million acre-feet. Much of this water is in shallow aquifers and is pumped extensively. In this area, the encroachment of saline water is threatening irrigation and municipal groundwater supplies.

Texas Gulf. The Texas Gulf Basin also has large supplies of groundwater, most of which occur in the unconsolidated sands and gravels of the Ogallala Formation. It is estimated that the formations contain 30 million acre-feet of good-quality water; however, large-scale pumping is depleting this resource. These waters are potable in most areas, though the TDS concentration varies from 200 to several thousand mg/l.

Surface Water

As mentioned above, the proposed main CO_2 pipeline would cross through four drainage basins from southwestern Colorado through New Mexico and into western Texas.

The first 135 miles of pipeline would pass through the San Juan River Basin. The pipeline would then cross the Rio Grande Basin for 147 miles, traverse the Pecos River Basin for 136 miles, and terminate in the Texas Gulf Basin. Specific rivers crossed by the main CO_2 pipeline would include the Mancos River near milepost (MP) 15, the La Plata River near MP 34, the Animas River near MP 58, the San Juan River near MP 71, the Rio Grande near MP 203, and the Pecos River near MP 378, as shown in Appendix F, Maps F-3 through F-10.

San Juan River Basin. The San Juan River Basin includes the entire drainage area of the Colorado River downstream from the junction of the Colorado and Green rivers, an area of about 38,644 square miles. The principal stream in the subregion is the San Juan River, the second largest tributary of the Colorado River which drains parts of southwestern Colorado, northwestern New Mexico, southeastern Utah, and northeastern Arizona. The Mancos, La Plata, and Animas rivers are all tributaries of the San Juan River.

The proposed main CO_2 pipeline would cross the Mancos River near Mancos, Colorado, 1 river mile downstream from the confluence of its west, middle, and east forks. Data from the only gaging station on the Mancos River, some 40 river miles downstream from the proposed pipeline crossing, indicates that the Mancos River is an intermittent stream with peak flows usually related to snowmelt and summer and fall thunderstorms (Table 2-7). Estimates of flood frequencies at the proposed pipeline crossing are presented in Table 2-8.

The proposed main CO_2 pipeline would cross the La Plata River near Kline, Colorado. Streamflow data from a gaging station just below the crossing (Table 2-7) again indicates a pattern of peak flows that reflect spring snowmelt and summer/fall thunderstorms. Flood flow estimates for this crossing are given in Table 2-8.

The Animas River would be crossed by the proposed main CO_2 pipeline near Aztec, New Mexico. Stream data from the Farmington, New Mexico gaging station downstream from the crossing indicate peak flows in May,

June, July and August (Table 2-7). The drainage area located upstream from this crossing causes predicted flood flows (Table 2-8) to range from 5,740 cfs (2-year flood) to 17,400 cfs (100-year flood).

After crossing the Animas River, the proposed main CO_2 pipeline would cross the San Juan River near Blanco, New Mexico, east of Farmington. Flow data from the gaging station at Farmington, New Mexico, some 25 miles downstream from the pipeline crossing, indicate a similar pattern for streamflow peaks (Tables 2-7 and 2-8).

A federal action of importance in the San Juan River Basin is the Navajo Indian Irrigation Project, which involves the diversion of water from the San Juan River via the Navajo Reservoir for the purpose of irrigating 110,630 Navajo-owned acres in northwestern New Mexico, south of Farmington.

While the quality of water in the San Juan Basin is generally good, turbidity and sediment levels are frequently high in many of its major watercourses (e.g., average annual flow weighted values for total dissolved solids range from 300 mg/l in the San Juan River at Farmington to 1190 mg/l in the Mancos River near Towaoc). The potential for sediment production in the San Juan basin within Colorado and especially New Mexico is particularly high. U.S. Geological Survey (USGS) data indicate that, in terms of whole production of the Colorado River as measured at Lee's Ferry, the San Juan at Shiprock, New Mexico produces 15.2 percent of the total flow and 29.4 percent of the suspended sediment.

Above Navajo Reservoir, average annual sediment production is estimated to be 0.5 acre-feet or 752 tons annually per square mile of drainage area (2,429,100 tons). More than 98 percent of this load is trapped in the reservoir, resulting in the release of nearly clear water. Large quantities of sediment, however, enter the San Juan from such ephemeral tributaries as Largo and Gobernador canyons below Navajo Dam; this stretch to the Bloomfield gaging station, which is 10 miles downstream from the proposed main CO_2 pipeline crossing, produces almost 2275 tons of sediment per square mile annually. The Animas and La Plata rivers contribute an estimated 604 tons and 208 tons, respectively, of sediment per square mile of drainage area, much of which is in Colorado. Most of the remainder of the basin in New Mexico is a plateau with a very high sediment yield potential, but the actual yield is lessened by the low average annual rainfall. Thus the total sediment load to pass the Shiprock gaging station (50 miles downstream from the main CO_2 pipeline crossing) is estimated to be only 8,721,900 tons or 676 tons per square mile of drainage. The sediment load of the Mancos River drainage in Colorado (about 780,000 tons) further contributes to this load just before the San Juan River leaves New Mexico.

Rio Grande Basin. The Rio Grande Basin consists of a series of connected basins that have filled with alluvial materials over time. The natural channel of the Rio Grande river is at least 200 to 300 feet wide and

braided. The main channel has been modified, however, and in several locations the entire flow of the river is carried in conveyance channels rather than in the main channel itself.

Periods of peak streamflow for the Rio Grande at San Felipe, New Mexico, located some 8 miles from the proposed pipeline river crossing, are listed in Table 2-7. Similarly, estimates of flood-frequency discharges at the crossing are given in Table 2-8. In general, flooding has been a recurrent problem along the Rio Grande and its tributaries.

The Rio Grande also carries a high sediment load. It has been estimated that the floodway near Albuquerque has aggraded 2 feet in 50 years. Spring floodflows have a severe scouring effect, which contributes sediment to this problem. For instance, it is estimated that the average annual sediment load is 1583 acre-feet in the Rio Grande near Bernardo and 600 acre-feet in the Jemez River above Jemez Canyon Dam.

Pecos River Basin. Surface flow of the Pecos River is erratic as a result of flood flows from heavy rains. At most of the gaging stations more than 70 percent of the annual runoff occurs during four months of of the year (Table 2-7).

Floods in the basin are of short duration and are usually caused by frontal and tropical storms. Most floods on record have occurred in the late summer months when the river and the numerous arroyos carry large volumes of water for short periods of time (see Table 2-8 for estimates of these flood flows).

Water issuing from the headwaters region is of good quality; however, the dissolved solids content increases downstream. For example, TDS levels consistently exceed several thousand mg/l at the Pecos River gaging station near Acme, New Mexico.

Texas Gulf Basin. There are no perennial surface streams in the Texas Gulf Basin in New Mexico; most of the water used in this area comes from the Ogallala aquifer. A few intermittent streams may flow following the thunderstorms common during July and August. There are no arroyos nor washes; the grassy surface drainage is controlled by a number of broad, shallow draws.

OIL FIELD

Groundwater

As discussed in the preceding section, the groundwaters in the area of the oil field are primarily in the unconsolidated sands and gravels of the Ogallala Formation. The Denver Unit, which is the unit tapped by the oil field, also has sizable quantities of water; however, this water is highly saline and of limited use.

Surface Water

No perennial streams exist within the boundaries of the oil field. The intermittent surface flows that do occur following the thunderstorms common during July and August are carried off of the site by a number of broad, shallow draws.

VEGETATION

The description of the existing vegetation in the project area is based on a site reconnaissance; discussions with local, state, and federal agency personnel; and information from published and unpublished documents including Owen (1974), BLM (1976a, 1976b, 1976c, 1977b), and Technology Application Center (1977). Characteristics of the vegetation relevant to anticipated impacts are described below for the CO_2 well field, the main CO_2 pipeline, and the oil field.

CO_2 WELL FIELD

Vegetation Types

The following nine vegetation types, which together cover 320,000 acres in the CO_2 well field (Table 2-9), are discussed below:

- Ponderosa pine forest
- Aspen woodland
- Pinyon-juniper woodland
- Mountain shrub
- Sagebrush
- Desert shrub
- Mountain grassland
- Riparian
- Agriculture

Ponderosa Pine Forest. The ponderosa pine vegetation type is present over 26,900 acres, or 8 percent, of the CO_2 well field. This forest vegetation occurs at elevations from about 7500 to 8500 feet east of the Dolores Canyon. Ponderosa pine trees dominate the overstory while Gambel oak, bitterbrush, Oregon grape, and snowberry are common components of the shrub understory. Grasses and forbs such as mutton bluegrass, junegrass, woodfern, penstemon, Indian paintbrush, balsamroot, and pussytoes are common species in the understory of the ponderosa pine forest. The understory vegetation provides forage at the rate of about 12 acres per animal unit month (AUM).

Table 2-9. VEGETATION IN THE PROJECT AREA

Vegetation Type	CO_2 Well Field (acres)	Main CO_2 Pipeline (miles)	Main CO_2 Pipeline (acres)*	Oil Field (acres)	Total (acres)	Total (%)
Ponderosa pine forest**	26,900	18	220	-	27,120	8
Aspen woodland	1,600	-	-	-	1,600	<1
Mountain grassland	2,100	-	-	-	2,100	<1
Pinyon-juniper woodland	171,700	46	570	-	172,270	49
Chained pinyon-juniper shrubland	22,200	-	-	-	22,200	6
Sagebrush	11,900	72	900	-	12,800	4
Desert shrub	14,700	2	30	-	14,730	4
Shinnery	-	9	110	-	110	<1
Desert grassland	-	210	2,570	-	2,570	<1
Plains grassland	-	88	1,090	25,600	26,690	8
Riparian	2,100	1	20	-	2,120	<1
Agriculture	66,800	32	390	-	67,190	19
TOTAL	320,000	478	5,900	25,600	351,500	100

*Includes acreage for right-of-way, origin station, compressor station, and microwave sites.

**Includes mountain shrub vegetation.

Aspen Woodland. Noncommercial aspen woodland occurs in scattered locations within the ponderosa pine forest and covers 1600 acres (1 percent) of the CO_2 well field. Quaking aspen trees are the dominant species in the overstory. The abundance of vegetation in the understory depends on the density of the aspen canopy and other site-specific conditions such as soil, slope, precipitation, and level of grazing. Snowberry and chokecherry are common species in the shrub understory. On wetter sites, several forbs such as meadowrue, vetch, western yarrow, larkspur, and columbine and grasses such as wildrye, fescue, brome, and junegrass may also be common.

Mountain Shrub. Mountain shrub vegetation often occurs at scattered locations at the ecotone or transition zone between the pinyon-juniper woodland and the ponderosa pine forest vegetation types. Acreage for mountain shrub vegetation is included in the acreage for ponderosa pine since the areas of mountain shrub are generally too small to delineate on vegetation maps. The location of the mountain shrub vegetation may be related to past fires as well as other factors such as soil, slope, exposure, and moisture availability.

The major shrub species include Gambel oak, snowberry, mountain mahogany, bitterbrush, skunkbrush, and sagebrush. A variety of forbs and grasses such as western wheatgrass, squirreltail grass, dogbane, harebell, aster, and groundsel may also occur in this vegetation type.

Pinyon-Juniper Woodland. Pinyon-juniper woodlands were present on much of the proposed CO_2 well field prior to extensive clearing operation for rangeland improvement and agricultural production. Pinyon-juniper woodlands presently occur on 171,700 acres (54 percent) of the CO_2 well field and dominate the mesa sides and unaltered mesa tops from elevations of about 5200 feet near McElmo Creek to about 7800 feet near the Dolores River.

Pinyon-juniper woodlands in the study area consist of a tree canopy dominated by Utah juniper and pinyon pine trees and an extremely sparse understory. The shrub understory generally consists of mountain mahogany with some big sagebrush, Mormon tea, rabbitbrush, snakeweed, antelope bitterbrush, and cliffrose. Grasses in the understory include galleta, Indian ricegrass, and squirreltail. This vegetation type typically provides livestock forage at the rate of 20 to 25 acres per AUM (DeKeyrel 1978).

Chained Pinyon-Juniper Shrubland. Chained pinyon-juniper shrubland is an artificial type that occupies 22,200 acres (7 percent) of the well field and is present on many of the uncultivated mesa tops. Much of this shrubland was established in the early 1960s when the trees were uprooted by dragging a heavy chain stretched between two bulldozers through the wooded areas. This practice was intended to increase herbage production and, hence, livestock grazing potential. Many of the trees were not completely uprooted and have since become reestablished.

Within the project area, this vegetation type presently consists of widely spaced Utah juniper and pinyon pine trees up to about 10 feet in height, several shrub species that dominate the vegetative ground cover, and some widely scattered grasses. Cliffrose, mountain mahogany, and rabbitbrush are common shrub understory species while crested wheatgrass, galleta, and Indian ricegrass are the dominant grass species. The chained pinyon-juniper shrublands provide livestock forage at the rate of 8 to 12 acres per AUM (DeKeyrel 1978).

Sagebrush. Sagebrush vegetation covers 11,900 acres (4 percent) of the CO_2 well field and is primarily present near the lower limits of the pinyon-juniper woodland vegetation. Sagebrush vegetation is a shrub-dominated type with an understory of grasses and some forbs. Shrubs typically include big sagebrush, black sagebrush, snakeweed, rabbitbrush, winterfat, and fourwing saltbush. Common grasses include galleta, Indian ricegrass, and alkali sacaton. Grazing potentials in this vegetation type generally average about 15 acres per AUM (DeKeyrel 1978).

Desert Shrub. The desert shrub vegetation type is similar in structure to the sagebrush type but occurs at the lower elevations of the CO_2 well field near McElmo Creek and adjacent to the riparian habitat along portions of Yellowjacket Creek. Desert shrub vegetation occupies about 14,700 acres (5 percent) of the CO_2 well field.

This shrub-dominated cover largely consists of fourwing saltbush, shadscale, and snakeweed. Grasses in the understory are dominated by galleta and alkali sacaton. Indian ricegrass and squirreltail grass are also present though generally less abundant. Approximately 15 to 20 acres of forage in this vegetation type are needed to provide one AUM (DeKeyrel 1978).

Mountain Grassland. Mountain grassland vegetation occurs on about 2100 acres (<1 percent) of the CO_2 well field in the area around Glade Lake and The Glade northeast of the Dolores River. Grasses and forbs in this vegetation type include muhly grasses, prairie junegrass, grama grasses, bluegrasses, dropseed grasses, globe mallow, Indian paintbrush, penstemon and pussytoes. Scattered big sagebrush, winterfat, skunkbush, Gambel oak, and other shrub species may occur in the periphery of the mountain grassland.

Riparian. Riparian vegetation covers approximately 2100 acres (<1 percent) of the proposed CO_2 well field and is confined to the areas adjacent to the Dolores River, McElmo Creek, Yellowjacket Creek, several other canyon bottomlands, and a few relatively small ponds and reservoirs scattered throughout the area. Tree species present in this vegetation include cottonwood, boxelder, Russian olive, tamarisk, willow, and Rocky Mountain maple. The schrub species associated with the riparian understory include fourwing saltbush, greasewood, and shadscale. Herbaceous species include cattails, sedges, rushes, alkali sacaton, saltgrass, and cocklebur.

Agriculture. Agricultural crops represent an artificial vegetation type that occupies about 66,680 acres (21 percent) of the CO_2 well field. Agricultural crops such as pinto beans, wheat, and sunflowers are present on many of the mesa tops. Truck garden crops such as corn, green beans, cantaloupe, and other vegetables and produce are grown along McElmo Creek.

Endangered and/or Threatened Plant Species

No plant species listed as endangered or threatened have been identified in the vicinity of the CO_2 well field (Federal Register 1976, U.S. Fish and Wildlife Service 1978a, 1978b). Eight plant species found in Dolores and Montezuma counties are candidates for the endangered and threatened list (Table 2-10). None of the candidate species were noted during brief reconnaissance surveys of the CO_2 well field area.

MAIN CO_2 PIPELINE

Vegetation Types

Nine vegetation types totaling 5900 acres are present along the proposed main CO_2 pipeline right-of-way and associated facilities (origin station, compressor station, communication sites). The woodland and forest vegetation types are generally associated with the higher elevations along the northern portion of the pipeline route while the grassland vegetation type is associated with the lower elevations primarily along the southern portion of the route (Figure 2-2).

Ponderosa Pine Forest. This vegetation type occurs along approximately 220 acres (18 miles) of the pipeline route in the area east of Cortez, Colorado. This vegetation is similar to the ponderosa pine forest vegetation previously discussed for the CO_2 well field.

Pinyon-Juniper Woodland. Pinyon-juniper woodland vegetation is present on about 570 acres of the pipeline system, including 560 acres (46 miles) of the right-of-way and about 10 acres at the Doran Mesa microwave site. Along the pipeline right-of-way, these woodlands are most common in the vicinity of the lower slopes of Menefee Mountain, the Colorado-New Mexico border, the Sandia Mountains, and Duran Mesa (Figure 2-2). The major plant species in this vegetation type are generally similar to those in the pinyon-juniper woodland vegetation type previously discussed for the CO_2 well field area.

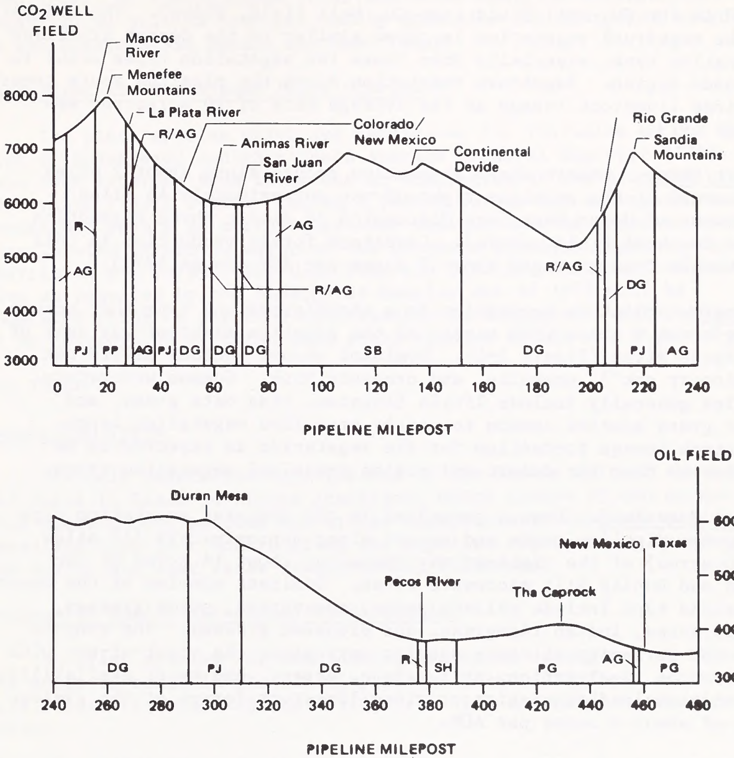
Sagebrush. Sagebrush vegetation is present on about 900 acres of the pipeline system. Approximately 878 acres are associated with the 100-foot pipeline right-of-way in the vicinity of the Continental Divide northwest of Albuquerque (Figure 2-2). The remaining 22 acres are present at the compressor station site and the Whitehorse and Black Mountain microwave sites.

Table 2-10. PROPOSED ENDANGERED AND THREATENED PLANT SPECIES IN MONTEZUMA AND DOLORES COUNTIES, COLORADO

Scientific Name	Common Name	Status	Known Distribution	Habitat
Aquilegia micrantha var. *mancosana*	Columbine	E*	Near Mancos River	Along creeks and springs
Astragalus deterior	Milkvetch	E	Montezuma County	Dry rocky mesas, sand-filled depressions, sandy talus slopes, in pinyon-juniper vegetation
Astragalus humillimus	Milkvetch	E	Near Mancos River	Crevices of rimrock pavement; sand-filled ledges of shelving rocks
Astragalus naturitensis	Milkvetch	E	Near Dolores River and McElmo Creek	Sandstone ledges and crevices of rimrock pavement along canyons, with pinyon-juniper at elevations of 5400-6200 feet
Astragalus schmollae	Milkvetch	E	Montezuma County	Dry mesas, pinyon-juniper woodland at elevation of 6000-8000 feet
Atriplex pleiantha	None	E	Near Mancos River	Barren clay slopes of low hills, 5100 feet
Echinocereus triglochidiatus var. *inermis*	Hedgehog cactus	E	Dove Creek area, Dolores County	Sagebrush and pinyon-juniper vegetation, 5000-8000 feet
Sclerocactus mesae-verdae	Mesa Verde cactus	E	Mesa Verde National Park; Ute Indian Reservation	Adobe hills, dry clay soils, 4000-5000 feet

Source: Based on U.S. Fish and Wildlife Service, 1978a.

*E = endangered.



LEGEND

AG - Agriculture
DG - Desert grassland
PG - Plains grassland
PJ - Pinyon-juniper woodland
PP - Ponderosa pine forest
R - Riparian
SB - Sagebrush
SH - Shinnery

Figure 2-2. DISTRIBUTION OF VEGETATION ALONG THE PIPELINE ROUTE

This vegetation type is generally similar to sagebrush vegetation found in the CO_2 well field (see CO_2 Well Field, above). The understory in the sagebrush vegetation is often similar to the desert grassland vegetation type, especially when those two vegetation types occur in the same region. Sagebrush vegetation along the pipeline route generally provides livestock forage at the average rate of 10 acres per AUM (Houpt 1979).

Desert Shrub. Desert shrub vegetation occurs along about 2 miles (30 acres) of the pipeline right-of-way approximately 45 miles northwest of Duran Mesa (see discussion of desert shrub vegetation under CO_2 Well Field, above). Livestock forage production in this vegetation type averages about 5 acres per AUM (Houpt 1979).

Shinnery. Shinnery vegetation is a shrub/grassland type that occurs along about 9 miles (110 acres) of the pipeline right-of-way east of the Pecos River (Figure 2-2). Dominant shrubs include Havard oak ("shinnery oak"), mesquite, and creosote bush. Common understory species generally include little bluestem, side oats grama, and other grass species common to nearby grassland vegetation types. Livestock forage production for the vegetation is expected to be similar to that for desert and plains grassland vegetation types.

Desert Grassland. Desert grassland is the dominant vegetation type along the pipeline route and occurs along approximately 210 miles (2570 acres) of the right-of-way including about 14 acres at the Ramon and Dunlap Sill microwave sites. Dominant species of the desert grassland type include galleta grass, cheatgrass, grama grasses, wheatgrasses, Indian ricegrass, and dropseed grasses. The composition and diversity of these species vary along the right-of-way with differences in elevation, soil, slope, aspect, and water availability. Desert grassland vegetation provides livestock forage at the average rate of about 6 acres per AUM.

Plains Grassland. Plains grassland occurs along approximately 88 miles (1090 acres) of the pipeline route and is the dominant vegetation type between the Pecos River and the Wasson Oil Field. Grama grasses and buffalo grass, are the major plant species, although three-awn grass, sand dropseed, and bluestem are also common in some areas. Although few shrub species are present, some scattered mesquite and rabbitbrush occur with the plains grassland vegetation type. Forage production in this vegetation type typically averages 6 acres per AUM.

Riparian. Riparian vegetation is associated with the pipeline crossings at the Mancos River, La Plata River, Animas River, San Juan River, Rio Grande, and Pecos River. Cottonwood and willow are the most common tree species; shrub species include fourwing saltbush, greasewood, and shadscale. Herbaceous species often include alkali sacaton and saltgrass. This vegetation type provides minimal livestock forage.

Agriculture. Agricultural lands are present along about 32 miles (390 acres) of the pipeline route and occur near the major river crossings as well as near the Sandia Mountains and scattered locations in southeastern New Mexico and West Texas.

Endangered and Threatened Plant Species

Ten plant species which are candidates for inclusion on the federal list of endangered and threatened species (Federal Register 1976) have been recorded from locations in the region of the proposed pipeline route (Table 2-11). During a recent survey for endangered and threatened plants in northwestern New Mexico, none of these species were located within 10 miles of the proposed pipeline right-of-way (Martin et al. 1978). The U.S. Fish and Wildlife Section 7 consultation as required by the Endangered Species Act of 1973 will be completed prior to pipeline construction to determine the location of any endangered or threatened plant species within the right-of-way.

OIL FIELD

Vegetation Types

The only vegetation type present in the Denver Unit of the Wasson Oil Field in Texas is plains grassland, which covers 25,600 acres. This vegetation type does not differ significantly from the plains grassland type that occurs along the pipeline right-of-way in eastern New Mexico and West Texas as previously discussed.

Endangered and/or Threatened Plant Species

No plant species (or candidates) listed as endangered or threatened are known to occur in the vicinity of the Wasson Oil Field near Denver City, Texas (Federal Register 1976, U.S. Fish and Wildlife Service 1978b).

FISH AND WILDLIFE

CO_2 WELL FIELD

Fish

The only major river in the CO_2 well field is the Dolores River. In addition, the well field contains McElmo and Yellowjacket creeks (both of which are permanent) several intermittent creeks, Glade Reservoir, and several small livestock ponds. The Dolores River, McElmo Creek, and, to a lesser extent, Yellowjacket Creek - the only aquatic habitats in the CO_2 well field with significant fish populations - are discussed below.

Table 2-11. PROPOSED ENDANGERED AND THREATENED PLANT SPECIES IN THE REGION OF PROPOSED PIPELINE ROUTE

Scientific Name	Common Name	Status	Distribution (county)
Aquilegia micrantha var. *mancosana*	Columbine	E*	Montezuma, CO
Astragalus deterior	Milkvetch	E	Montezuma, CO
Astragalus humillimus	Milkvetch	E	Montezuma, CO
Astragalus naturitensis	Milkvetch	E	Montezuma, CO
Astragalus schmollae	Milkvetch	E	Montezuma, CO
Atriplex pleiantha	None	E	Montezuma, CO
Sclerocactus mesae-verdae	Mesa Verde Cactus	E	Montezuma, CO
Pediocactus knowltonii	None	E	San Juan, NM
Petalostemum scariosum	Prairie Clover	E	Bernalillo, NM
Astragalus siliceus	Milkvetch	E	Torrance, NM

*E = endangered.

Sources: U.S. Fish and Wildlife Service 1978a, Spellenberg 1976.

Dolores River. The Dolores River flows through about 11 miles of the CO_2 well field and experiences a fluctuating flow controlled by a reservoir in Narraguinnep Canyon. A small population of trout and warm-water fish, including catfish and suckers, is reported in the vicinity of the reservoir. Deep pools are reported to contain rainbow and native trout (U.S. Forest Service [USFS] 1968).

McElmo Creek. McElmo Creek flows through about 16 miles of the extreme southern portion of the well field. Though this creek is known to contain several fish species, it is not considered a major creek for game fish and has not been extensively examined in the past. The Colorado Division of Wildlife (CDOW) collected seven species of fish (flannel mouth sucker, channel catfish, fathead minnow, zebra minnow, mottled sculpin, speckled dace, and green sunfish) during a recent survey of McElmo Creek (Smith 1978, personal communication). Water quality in McElmo Creek is considered unacceptable to maintain major populations of any game species such as trout (Smith 1978, personal communication). The major sources of pollution are sewage discharges from the city of Cortez and runoff from the agricultural fields along the creek and on the mesa tops adjacent to the creek.

Yellowjacket Creek. Within the CO_2 well field, Yellowjacket Creek extends for about 25 miles from near the town of Yellow Jacket to the southwestern corner of the well field. Because Yellowjacket Creek flows into McElmo Creek approximately 1 mile west of the CO_2 well field, all of the fish species known to occur in McElmo Creek could also occur in Yellowjacket Creek.

Wildlife

The variation in plant species and vegetation communities associated with topographic features in the CO_2 well field provides a number of habitat types that support many species of wildlife. Although most of these wildlife species are not restricted to particular vegetation types, some show an affinity for certain plant associations, soil types, and topographic configurations (e.g., cliffs, bluffs, and canyons). Vegetation-dependent animals, such as many small birds, rodents, and numerous invertebrates, tend to have small territories or home ranges relative to the area of the vegetation type. Conversely, species such as the coyote, skunk, hawks, and owls which are not restricted to specific vegetation types range over large areas and several vegetative communities. The major wildlife habitats, their acreages in the CO_2 well field, and several dominant wildlife species associated with each are as follows:

- Ponderosa pine forest (includes mountain grassland, aspen woodland, and mountain shrub) (30,600 acres): Elk, mule deer, coyote, porcupine, least chipmunk, chickadee, pinyon jay.

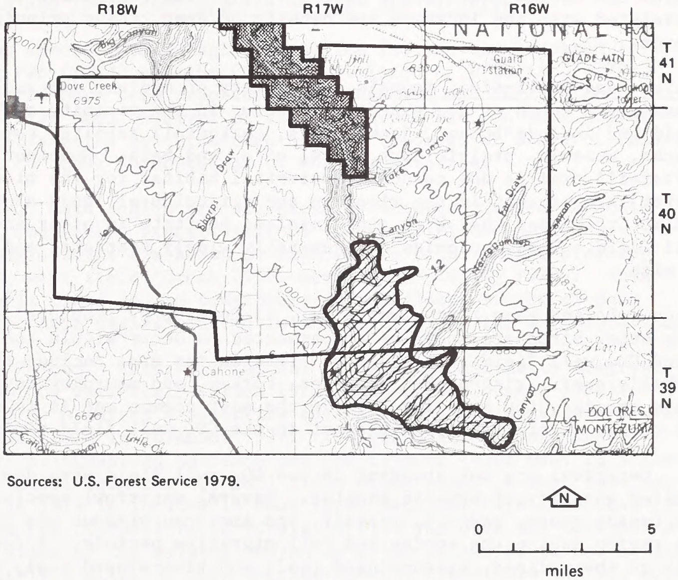
- Pinyon-juniper woodland (171,700 acres): Mule deer, coyote, black-tailed jackrabbit, desert cottontail, pinyon jay, least chipmunk, deer mouse.
- Shrublands (sagebrush/desert shrub/chained pinyon-juniper) (48,800 acres): Mule deer, badger, coyote, desert cottontail, black-tailed jackrabbit, least chipmunk, deer mouse, horned lark, lark bunting.
- Riparian (2100 acres): Mule deer, raccoon, muskrat, marsh hawk, mallard, killdeer, robin, western kingbird.
- Agriculture (66,800 acres): Meadowlark, mourning dove, deer mouse, striped skunk, Richardson's ground squirrel.

A complete list of wildlife species within the region, including the vicinity of the CO_2 well field, is available at the BLM Montrose District Office. Several species of particular concern could be impacted by construction and/or operation of the proposed CO_2 well field facilities, and are discussed below.

Large Mammals. Mule deer, elk, black bear, and mountain lion occur in the region of the proposed CO_2 well field. Mule deer are widely distributed throughout the area and are the most important big game species in terms of numbers and recreational value. The vicinity of the proposed CO_2 well field encompasses year-round and seasonal mule deer habitat including some crucial winter range (USFS 1979). The crucial winter range consists of about 5000 acres between Dolores and Narraguinnep canyons (Map 2-2). There are also several seasonal deer migration routes within and adjacent to the Doe Canyon Field of the proposed CO_2 well field (CDOW 1977a); based on information from CDOW (Gresh 1979), an estimated 1500 mule deer are present in the CO_2 well field vicinity during the winter and as many as 6000 during the summer.

The Rocky Mountain elk is generally found at the higher elevations in mixed coniferous forests of the San Juan Mountains; however, elk utilize the portion of the CO_2 well field area east of the Dolores River. Vegetation types in this area (ponderosa pine, mountain shrub, mountain grassland, aspen) provide seasonal and year-long elk habitat including some crucial winter range (CDOW 1977a, USFS 1979). The crucial elk winter range in the well field consists of about 5000 acres that coincides with the crucial mule deer winter range (Map 2-2). Approximately 850 elk are estimated to occur in the CO_2 well field vicinity (all in the Doe Canyon Field) during the winter and 200 to 300 in the summer, based on information from the CDOW (Gresh 1979).

Black bears are found primarily on forested slopes northeast of the Dolores River where human disturbance has not significantly



LEGEND

- Mule Deer and Elk Crucial Winter Range
- Prime Peregrine Falcon Habitat
- Boundary of Doe Canyon Field

Map 2-2. BIG GAME AND PEREGRINE FALCON HABITATS

altered the land. Approximately 25 to 30 black bears occur in the Doe Canyon Field, based on recent regional estimates (Gresh 1979).

Approximately ten mountain lions are estimated to occur in the Doe Canyon and McElmo Dome fields (Gresh 1979). Their location is generally correlated with the location and density of deer, their principal food source.

Medium- and Small-Sized Mammals. A variety of medium- and small-sized mammals are known or are expected to occur in the vicinity of the well field and include bobcat, jackrabbits, cottontail rabbits, coyotes, skunks, weasels, prairie dogs, rats, mice, and bats. Gunnison's (or whitetail) prairie dog colonies (potential habitat for the black-footed ferret) are present in the riparian and agricultural lands along McElmo Creek, and the shrub and grassland habitats in other areas of well field. These colonies are generally widely scattered and small in size.

Birds. Upland game birds, waterfowl, birds of prey (raptors), and many other birds are known or are expected to occur within the proposed CO_2 well field. Upland game birds in the area include the Gambel's quail, ring-necked pheasant, turkey, and mourning dove. Of these species, the mourning dove is the most common and is found in all of the vegetation types present in the CO_2 well field vicinity.

Waterfowl are not abundant in the CO_2 well field area due to the limited quantity of aquatic habitat. Several waterfowl species such as the Canada goose, gadwall, pintail, and American widgeon are present in the region during the spring and fall migration periods. A few species, such as the mallard, green-winged teal, and blue-winged teal, may also breed in the region, though any breeding populations in the well field area would be small due to limited aquatic habitat.

Birds of prey present in the well field vicinity include two species of eagles, seven species of owls, six species of hawks, two species of falcons, and the osprey. The red-tailed hawk, golden eagle, marsh hawk, and American kestrel are the most common resident species of raptors in southwestern Colorado that may nest within the CO_2 well field. The rough-legged hawk and bald eagle are winter visitors to the region and are occasionally observed in the well field.

Reptiles and Amphibians. Although amphibians are generally restricted to the aquatic and riparian habitats of the well field, several species of snakes and lizards are present throughout much of the area, especially at the lower elevations. A rare lizard and snake natural area has been proposed by the BLM for an area of about 480 acres adjacent to the Utah border and about 2 miles north of McElmo Creek (see Appendix F, Map F-1). Of particular interest in this proposed natural area are three species of reptiles - the long-nosed

leopard lizard, twin-spotted spiny lizard, and Mesa Verde night snake - whose distributions in Colorado are generally limited to the extreme southwestern part of the state.

Endangered and Threatened Species of Fish and Wildlife

Three species (bald eagle, peregrine falcon, black-footed ferret) listed by FWS (1977) and the Colorado Division of Wildlife (1978c) as endangered have been reported from Montezuma and Dolores counties that have also been observed or could occur in the CO_2 well field. No other endangered or threatened species (federal or state of Colorado) are known to occur in Montezuma or Dolores counties.

Bald Eagle. Bald eagles are occasionally observed in the CO_2 well field but considered winter visitors (Gresh 1978, Button 1978). No bald eagle nests are known or expected to occur in the vicinity of the CO_2 well field (Gresh 1978, Button 1978, Craig 1978). Thus the CO_2 well field can be considered an occasional source of prey species for bald eagles hunting in the vicinity during the winter.

Peregrine Falcon. Peregrine falcons are also occasionally observed within the CO_2 well field (Gresh 1978, Button 1978, Craig 1978). Button (1978) observed a peregrine falcon in the northern part of the McElmo Dome Field in November 1977. Peregrine falcons are known to nest in southwestern Colorado and the closest known nest location is over 5 miles from the CO_2 well field study area. A nest that was inactive in 1978 is located in Mesa Verde National Park more than 10 miles from the CO_2 well field (Craig 1978). The USFS has designated about 20 miles of the Dolores Canyon as prime peregrine falcon habitat. Approximately 5 miles of this designated area are within the CO_2 well field (Map 2-2).

Black-footed Ferret. The endangered black-footed ferret has been reported near Mancos, Colorado and Blanding, Utah, or about 25 miles east and 25 miles west of the CO_2 well field, respectively (Cahalane 1954, Armstrong 1972, Durrant 1952). The existence of the black-footed ferret anywhere in Colorado at the present time cannot be confirmed due to the absence of any recent sightings (CDOW 1978b). Although the probability of a black-footed ferret present within the CO_2 well field is estimated to be small, such an occurrence cannot be discounted entirely since Gunnison's (or whitetailed) prairie dogs, whose distribution has historically coincided generally with that of the black-footed ferret, are present in the vicinity of McElmo Creek in the extreme southern portion of the CO_2 well field (Gresh 1978).

MAIN CO_2 PIPELINE

Fish

The main CO_2 pipeline would cross six major streams that support fish populations: the Mancos and La Plata rivers in Colorado; and the Animas, San Juan, Rio Grande, and Pecos rivers in New Mexico.

Mancos River. In the vicinity of the pipeline crossing (approximately 15 miles east of the well field), the Mancos River is a permanent stream containing trout and several warm-water species (fathead minnows, shiners, and roundtail chub).

La Plata River. The La Plata River crossing (west of Durango) has waterflow throughout the year although irrigation requirements often significantly reduce the flow in downstream areas. Trout are present near the pipeline crossing. Catfish, suckers, carp, and sunfish are common in the downstream areas and may also be present near the pipeline crossing.

Animas River. The Animas River, which would be crossed approximately 10 miles northeast of Farmington, supports populations of trout (mostly rainbow) as well as some warm-water species.

San Juan River. The San Juan River crossing (east of Farmington) is below Navajo Dam and provides excellent rainbow and brown trout habitats. Downstream from the proposed crossing, increasing turbidity and warmer water provide habitat for warm-water species such as largemouth bass, white crappie, bluegill, channel catfish, carp, suckers, shinners, and minnows.

Rio Grande. In its middle reaches, the Rio Grande consists of a 200- to 300-ft wide channel with high turbidity. Near the proposed pipeline crossing, the channel is braided and experiences periodic flooding. A cold-water rainbow trout fishery is present for about 23 miles from Cochiti Dam north of Albuquerque to Angostura Irrigation Division Structure a few miles north (upstream) of the pipeline crossing. In the vicinity of the pipeline crossing, the aquatic habitats are limited due to sedimentation, fluctuating flows, and water diversion. Fish species reported in the above regions of the Rio Grande include the channel catfish, walleye, bluegill, sunfish, gi zard shad, and carp.

Pecos River. The proposed pipeline route crosses the Pecos River about 20 miles north of Roswell. In its upper reaches, the Pecos River is a fine trout stream, with rainbow, native, and brown trout. In the downstream portions near the proposed pipeline crossing, it becomes a warm-water river. Catfish, bluegill, and largemouth bass comprise the major game fish near the proposed crossing.

Wildlife

The major wildlife habitats and the lengths they extend along the proposed pipeline route are as follows:

- Ponderosa pine forest (including mountain shrub)(18 miles)
- Pinyon-juniper woodlands (46 miles)
- Shrublands (including sagebrush, desert shrub, and shinnery) (83 miles)
- Grassland (including desert and plains grasslands)(290 miles)
- Riparian (1 mile)
- Agriculture (40 miles)

The ponderosa pine, pinyon-juniper, shrublands, riparian, and agriculture habitats along the pipeline generally support the same species or groups of wildlife found in similar habitats in the CO_2 well field. The grassland habitat found along the pipeline route does not occur in the well field; major species in this habitat include the pronghorn antelope as well as many of the same species of smaller mammals and birds as the shrubland habitat.

Large Mammals. Mule deer, whitetail deer, pronghorn antelope, and, to a lesser extent, elk represent the major big game species that occur along the pipeline route. Mule deer are associated with the ponderosa pine forest, pinyon-juniper woodland, sagebrush, and riparian habitats located between the CO_2 well field and the Rio Grande and near the Sandia Mountains, the Caprock area, and the major river crossings. Most of this habitat is year-round range although concentration areas are present near the Continental Divide crossing (near milepost [MP] 135) and on Mesa San Luis (near MP 160). The Continental Divide area is the only area along the proposed route that has been identified as a principal wintering ground for mule deer.

A relatively small isolated population of whitetail deer are also located in the shinnery dominated habitat east of the Pecos River and in the Mescalero Sand Dune area. Three major dune areas are expected to provide crucial winter habitat within the Mescalero Dunes (BLM 1975).

Pronghorn antelope occur in the grassland and shrubland habitats along the pipeline route in New Mexico. Currently, antelope are not numerous in areas traversed by the proposed pipeline route. The populations and habitats along the route are considered stable by the New Mexico Department of Game and Fish (NMDGF)(1977); however, the population trend is down and the habitat is deteriorating for the population north of Highway 17.

Elk occur along the western slopes of the Sierra Nacimiento and La Ventana Mesa northwest of Albuquerque and several miles northeast of the pipeline route. During the winter, some elk from these areas may move into the rolling hills and flatlands adjacent to the pipeline route near San Luis (MP 165).

Medium- and Small-Sized Mammals. Many of the same species and/or types of medium- and small-sized mammals that are present in the well field area also occur along the proposed pipeline route. These mammals include the bobcat, jackrabbits, cottontail rabbits, coyote, skunks, prairie dogs, rats, mice, and bats. The distribution of prairie dogs along the pipeline route is important since prairie dog colonies provide habitat for black-footed ferrets. A number of prairie dog colonies occur throughout much of the grassland and shrubland habitats along the proposed route. The whitetail prairie dog occurs along these habitats primarily in northwestern New Mexico, while the blacktail prairie dog is present in eastern New Mexico.

Birds. Upland game birds, waterfowl, raptors, and many other species of birds occur in the habitats along the proposed pipeline route. The mourning dove, as in the well field area, is the most abundant upland game species and occurs along the entire pipeline route.

The scaled quail is a resident of the arid grasslands along the route in northwestern New Mexico, although it does range up to the fringes of the pinyon-juniper woodland. Highest concentrations usually occur in riparian areas of mixed desert grassland/shrub vegetation and brushy draws. The populations are cyclic and fluctuate greatly in relation to annual precipitation.

A general lack of permanent water systems other than the major river crossings limits potential waterfowl nesting habitat along the pipeline route. Most of the waterfowl species that occur along the pipeline route are not year-round residents but use these areas during migration periods in the spring and fall. The Bitter Lake National Wildlife Refuge northeast of Roswell, New Mexico is within about 1 mile of the proposed pipeline route. This refuge is the most important waterfowl area in eastern New Mexico and contains the most diverse aquatic habitat in the Pecos River watershed. The lesser sandhill crane is a water associated species that winters in large numbers along the Pecos River and at the Bitter Lake Refuge.

Raptors have a broad areal distribution in the region of the proposed pipeline route. Prairie falcons and golden eagles, as well as the peregrine falcon and bald eagle, occur in parts of the San Juan River Valley, Rio Grande Valley, and Pecos River Valley. Several additional species of hawks and owls are found throughout the region.

Reptiles and Amphibians. Many species of lizards, snakes, frogs, toads, and salamanders occur along the proposed pipeline route. A list of these species can be obtained from the BLM District office having jurisdiction over each particular region of the pipeline route.

Endangered and/or Threatened Species of Fish and Wildlife

Twenty-seven species of fish and wildlife along the proposed pipeline route are on the United States, New Mexico, or Colorado lists of endangered and threatened species (Federal Register, 1976; New Mexico State Game Commission, 1976; Colorado Division of Wildlife, 1978). These species include 13 fish, 1 mammal, 9 birds, 3 reptiles, and 1 amphibian as discussed below.

Fish. The Colorado River squawfish and the Pecos gambusia are the only endangered fish species that occur on the federal, New Mexico, and Colorado lists of endangered species. The range for the Colorado River squawfish species includes the Mancos, Animas, and San Juan river drainages. The Pecos gambusia is restricted to seven isolated populations within the Bitter Lake National Wildlife Refuge near Roswell, New Mexico. Eleven additional species on the New Mexico list may also occur within rivers crossed by the proposed pipeline route: the humpback sucker in the Mancos and San Juan rivers; the roundtail chub in the Animas and San Juan rivers; the bluntnose shiner, proserpine shiner, shovelnose sturgeon, and American eel in the Rio Grande; the Mexican tetra, roundnose minnow, Pecos pupfish, greenthroat darter, and rainwater killifish in the Pecos River.

Wildlife. Species on the federal list of endangered and threatened species that have been observed or may occur along the pipeline route include the black-footed ferret, peregrine falcon, bald eagle, and whooping crane. The endangered black-footed ferret occupies grassland habitat in association with priarie dogs, which may constitute up to 90 percent of the ferret's diet. Although no confirmed sightings have been recorded for black-footed ferrets on any part of the pipeline right-of-way, their presence cannot be discounted. Recent sightings have been reported from Valencia, McKinley, Los Alamos, and Curry counties (NMDGF 1978).

The endangered peregrine falcon has been observed during migrations or during the winter at widely scattered locations throughout much of Colorado, New Mexico, and Texas; however, this species presently breeds in local mountainous regions not crossed by the proposed pipeline route.

The endangered bald eagle is also occasionally observed in the vicinity of the pipeline. Though generally considered a winter visitor in most areas, it has been sighted during the summer near Navajo Lake in northwestern New Mexico. No known bald eagle nests exist within nor adjacent to the proposed pipeline route.

A portion of a whooping crane population from Idaho migrates to the central Rio Grande Valley in the fall and most remain during the winter.

Six other species of birds whose distributions include the pipeline route are considered either endangered (little blue heron) or threatened ("endangered group V") (red-headed woodpecker, Baird's sparrow, osprey, least tern and McCown's longspur) by the state of New Mexico.

Three reptile species, the sagebrush sand dune lizard, the western ribbon snake and the slider turtle and one amphibian, the cricket frog are also listed as threatened by the state of New Mexico.

OIL FIELD

Fish

No fish populations are present in the oil field area due to the lack of aquatic habitat.

Wildlife

The wildlife populations in the oil field are essentially the same as those found in the plains grassland habitat previously discussed for the most southern portion of the pipeline route. The most common animals expected in this area include the coyote, horned larks, mourning dove, jackrabbits, cottontail rabbits, and several species of rodents and other small birds. No major populations of any big game species are expected to occur in the vicinity of the oil field.

Endangered and/or Threatened Fish and Wildlife Species

No endangered or threatened species are known to occur in the oil field area near Denver City, Texas. It is possible that the wide ranging, endangered peregrine falcon and bald eagle could be observed in the oil field area during migration, but no suitable nesting habitat for either species is present in the oil field.

CULTURAL RESOURCES

CO_2 WELL FIELD

Archaeological Resources

The area within the productive limits of the proposed CO_2 well field has likely been occupied on a temporary or permanent basis by

human populations for the past 10,000 years.* A total of 1367 known archaeological site locations have been recorded within the Doe Canyon and McElmo Dome sections of the CO_2 well field on BLM, National Park Service (NPS), U.S. Forest Service (USFS), and private lands. None of these sites is on the National Register.

Of 3085 recorded archaeological site occupations** in the CO_2 well field, approximately 71 percent have been dated from the Late Pueblo II (Mancos), Early Pueblo III (McElmo), and Late Pueblo III (Mesa Verde) phases of Anasazi occupation (Table 2-12). Approximately 43 percent of these site occupations consist of habitations with two or less kivas or pithouses (Table 2-13); about 44 percent represent limited activity or limited occupation sites; the remaining 13 percent are large habitations with great kivas, habitations with three or more kivas or pithouses, or special-use sites.

A computer model developed for the Shell portion of the CO_2 well field has predicted the likelihood of archaeological sites located in specific areas (or cells) of about 3.7 acres in size (see Appendix D, Well Field Development Plan, for a description of modeling techniques). Based on model findings, 52,015 of 52,648 cells in the Shell units of the CO_2 well field cells (or approximately 99 percent of the field) are expected to contain no archaeological sites. The Well Field Development Plan for the Mobil portion of the CO_2 well field is presently incomplete.

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*The chronological framework used is as follows and is discussed briefly under Main CO_2 Pipeline.

Paleoindian Period	10,000-6000 B.C.
Archaic Period	6000 B.C.-A.D. 450
Anasazi Period	A.D. 450-1300
Shoshonean-Athabascan Period	A.D. 1300-1880
Early Historic Period	A.D. 1880-1930

**A single site location may have been occupied during more than one period or phase.

Note: Information on cultural resources related to the project study area was obtained from the following sources:

New Mexico State University, Department of Sociology and Anthropology, Cultural Resources Management Division. 1978. Director: S. Bussey, Ph.D. Principal Investigators: P. Beckett, D. Bussey, K. Laumbach, P. Magers, T. Sudar-Murphy.
University of Colorado. 1978. Mesa Verde Regional Research Center, Dove Creek, Colorado. Director: D. Breternitz, Ph.D., Principal Investigators: A. Kane, P. Nickens.

Table 2-12. RECORDED SITE OCCUPATIONS* IN THE CO_2 WELL FIELD

Period of Occupation	Recorded Occupations
Unknown	59
Archaic	86
Basketmaker II	10
Anasazi	
Basketmaker III (La Plata)	243
Pueblo I (Piedra)	241
Early Pueblo II (Ackmen)	255
Late Pueblo II (Mancos)	820
Early Pueblo III (McElmo)	751
Late Pueblo III (Mesa Verde)	611
Post-Anasazi	
Athabascan-Shoshonean Tradition	9
TOTAL	3085

*A single site location may have been occupied during more than one period or phase.

Table 2-13. RECORDED SITE OCCUPATIONS* IN CO_2 WELL FIELD BY OCCUPATION TYPE

Occupation Type	Recorded Site Occupations
Large habitation with great kiva	15
Large habitation with 3 or more kivas or pithouses	309
Special-use sites: reservoirs or towers	73
Habitations with 2 or less kivas or pithouses	1329
Limited activity or limited occupation sites, including camps, field houses, farm houses; and unusual features, including terraces, check dams, petroglyphs, and pictographs	629
Limited activity sites including food and lithic processing areas, quarries, hunter outposts, and isolated storage facilities	730

*A single site location may have been occupied during more than one period and phase.

The CO_2 well field is divided into northern and southern sections: the northern, or Doe Canyon Field, is centered on the Dolores River Canyon in southern Dolores County; the southern, or McElmo Dome Field, includes the plateau west of U.S. Highway 666 and portions of the Woods Canyon and McElmo Canyon drainages. A brief, generalized discussion of each period of occupation and site types which may be encountered can be found under Main CO_2 Pipeline, below.

Doe Canyon Field. The archaeology of the Doe Canyon Field is not as well known as that of the McElmo Dome Field. Only 71 archaeological sites have been recorded for an area of about 130 square miles. Although some of the recorded sites have been dug or vandalized, no scientific excavations have been conducted within this section. Few scientific excavations exist outside the Doe Canyon Field that are close enough to have some bearing on this study.

A few institutional surveys have located sites within the Doe Canyon Field. A Mesa Verde Research Center crew examined 300 acres in 1971 and recorded three sites near the west rim of the Dolores River Canyon in the Doe Canyon Quadrangle. In 1974, a Research Center crew surveyed approximately 3 square miles of land in 15 sections of the Cahone Quadrangle within the limits of the section and recorded 30 archaeological sites. In 1975, a Research Center crew surveyed the Dolores River Canyon and located five prehistoric sites within margins of the section (in the Doe Canyon and The Glade USGS quadrangles). The most recent survey in the Doe Canyon Field took place in 1976 in two tracts of USFS land where timbering activities had been projected. During the survey, a total of 9.5 square miles in the Secret Canyon, Doe Canyon, and Narraguinnep Mountain USGS quadrangles were investigated; 27 sites were recorded within limits of the CO_2 well field.

Occupation of the area by human populations probably began about 10,000 to 12,000 years ago when peoples of the Paleoindian culture (10,000-6000 B.C.) are known to have been in the Four Corners area. Though no direct evidence exists for the presence of Paleoindian peoples in the Doe Canyon Field itself, diagnostic artifacts of the culture have been recovered within a 20-mile radius. Evidence of Paleoindian occupation in the Doe Canyon Field will most likely be camps located near permanent springs and other permanent water sources.

Permanent populations within the Doe Canyon Field probably became established during the Archaic Period (6000 B.C.-A.D. 450). Occupation during this time span was characterized by small bands of peoples with a hunting-gathering subsistence base who seasonally camped at certain locations within the margins and in the vicinity of the field. Springs and overlooks were preferred camping locations. Thirteen sites classified as camps have been recorded within the Doe Canyon Field; most were presumed in use during the Archaic Period. A comparison of site densities suggests that the Dolores River Canyon, including rim areas, was more intensively used by Archaic peoples than

the plateaus to the east and west. It has been suggested that the canyon served as the focal point of the local Archaic economy due to its wide range of environments and resources.

Hunting-gathering cultures gradually gave rise to a culture largely dependent on dryland farming. These farming peoples, or the Anasazi, (A.D. 450-1300), lived in permanent communities next to their agricultural plots. Reliance on domesticated crops as a major part of the subsistence base resulted in radical shifts in settlement and demographic patterns as well as a complex social system. That part of the Doe Canyon Field west of the Dolores River Canyon was heavily settled during the La Plata and Piedra phases (A.D. 450-900) of the Anasazi Period. Farming hamlets and villages were built on the deep soil areas of the mesa tops; in the area of most intense settlement population density was about 8 per square mile. Areas on the western plateau above 7600 feet, the Dolores River Canyon within the field, and the eastern plateau were unsuitable for agriculture. In these areas, the Anasazi practiced the foraging techniques of their archaic predecessors, harvesting the local wild game and plants during seasonal visits. Omitting the farming areas, site density in the Doe Canyon Field during the Anasazi Period was only 0.95 site per square mile, indicating a major reliance upon agriculture.

After abandonment of the area by the Anasazi in the early 1300s, the Doe Canyon Field probably knew only sporadic visitations and use until the advent of modern western settlement. Historic Shoshonean (Ute) and Athabascan (Navajo) peoples are known to have been in the area. In his account of the Escalante-Dominguez expedition in 1776, Fray Escalante mentions that the Dolores area was the homeland of the Muhuaches (Ute) Indians and documents several encounters with the local inhabitants. Navajo sites are known from the Cajon Mesa area; types of sites recorded include corrals, sweat lodges, and camps. Navajo peoples probably did not move into the Montezuma-Dolores area until the 18th and 19th centuries. Only one site (a sweat lodge and fire pit) representative of the Shoshonean-Athabascan occupation has been documented within the Doe Canyon Field. It can be concluded that the Ute and Navajo peoples visited the area on an irregular basis.

McElmo Dome Field. The McElmo Dome Field of the CO_2 well field encompasses approximately 372 square miles in a roughly rectangular tract situated a few miles west of Cortez, Colorado. Archaeologically, the section is located in the center of the Yellowjacket District of the Mesa Verde Region of the Anasazi Indians, an area well known for its proliferation of ancient ruins. Approximately 56 square miles of this study area have been surveyed for prehistoric and historic sites, resulting in 1296 recorded archaeological locations; in addition, a few sites within the section have been scientifically excavated. Other surveys and excavations have been conducted in nearby localities in the Yellowjacket District, thus adding to the data base being used to reconstruct the prehistory of the study area.

Human occupation of the McElmo Dome Field probably began about 10,000 years ago during the Paleoindian Period (10,000-6000 B.C.). While no positive evidence of the presence of Paleoindian hunting groups has been discovered within the section itself, diagnostic artifacts of the late Paleoindian Period have been recovered from the Hovenweep locality to the west and from the foothills of the San Juan Mountains to the northeast. Several prehistoric sites within the section have been identified as possible Paleoindian camps, although no diagnostic artifacts have been recovered in their vicinity. These sites are located on canyon rims and provide a good vantage point of the slopes below and of the opposite rim, a desireable characteristic in choosing a camping location.

Archaeological evidence from the section is equally slight for the Archaic Period (6000 B.C.-A.D. 450). No sites have been positively identified as possessing an early or middle Archaic component, although some tentative locations have been identified by using comparative data from other local areas within the Yellowjacket District. More than 20 sites with Archaic culture material have been reported from the Hovenweep locality to the west, and Archaic occupations have been identified in the plateau area on both sides of the Dolores River Canyon to the north.

After A.D. 1, the local Archaic peoples began to experiment with small-scale horticulture, perhaps introduced along with domesticated corn and other crops via trading networks from cultures to the south. This transitional time span between the end of the Archaic Period and the beginning of the Anasazi Period is often termed "Basketmaker II" or the "En Medio Phase" by archaeologists. A few dry rock-shelters in the Sand and Rock canyons locality in the southwest quarter of the section contain evidence of the presence of these peoples in the form of storage cists and other architecture. It is probable that other groups representative of this transitional culture also inhabited the plateaus and mesa tops in the north and northeast portions of the McElmo Dome Field, although no sites from this period have been discovered.

After A.D. 450, local inhabitants began to rely on agriculture as a major subsistence strategy. This began the Anasazi Period (A.D. 450-1300), a period of sophisticated farming and complex social and settlement systems. A few groups remained in Sand and Rock canyons, but the majority of the population lived in the plateau environmental zone in the north and northeast portions of the section. The lifestyle and general culture of these peoples was probably very similar to the population living in the Doe Canyon Field 10 miles to the north. The agricultural plots were located in deep soil areas on mesa tops, generally between 7100 and 6200 feet in elevation.

Aggregation of Anasazi population into large villages and ceremonial centers became the pattern by A.D. 900. The rock-shelter habitations in the southwest quarter were abandoned and the population was concentrated in large communities on the mesa tops.

After A.D. 900, a major change in settlement patterns took place. The large population centers could not be supported by the reduced yields of drought-ravaged fields, and small family groups migrated to local areas, such as seeps and drainage bottoms, where groundwater was still available for domestic crops. Most of these small habitations were still located in the plateau zone in the north and northeast portions of the section; site densities in the southern and western portions remained very low.

The Mancos Phase (A.D. 975-1075) of the Anasazi Period was a period of population growth and territorial expansion within the McElmo Dome Field. The plateau zone continued to be heavily exploited; when the mesa tops became crowded, new communities were established in other local environments, such as in the cap rock zone (large habitations were constructed along canyon rims) and in the canyon bottom zone (such as along the watercourses in Yellow Jacket and Woods canyons). The rock-shelters in the cliff zone in Sand and Woods canyons, which had been abandoned for nearly 300 years, were reoccupied. A comparison of habitation densities suggests a three- or four-fold increase in population levels during this period . While the economy continued to be based primarily upon dry farming, there is evidence of increased use of more intensive agriculture techniques such as floodwater farming, terracing, and irrigation. Ceramic evidence indicates several large prehistoric reservoirs (such as the examples within the study area at Moqui and at Goodman Lake) were built during this period, perhaps to augment the domestic water supply. The beginnings of a habitation hierarchy are evident, with central communities probably serving as focal points for intercommunity activities. Goodman Point Ruin and a site located near Woods Canyon were probably two such large centers within the field.

By A.D. 1300, the McElmo Dome Field, as well as the entire Four Corners area, was abandoned by the Anasazi, perhaps as the result of another drought or a final exhaustion and degradation of the farming environment.

Evidence of roads or trails used by the Anasazi culture may be present in McElmo Dome Field. Anasazi roads are known from the Chaco Canyon area and it is possible other roads and trails along trading routes led north into the Yellowjacket area. Natural avenues of approach within the field where one would likely find traces of prehistoric roads or trails are McElmo Canyon (east-west access), Yellowjacket Canyon (northeast-west access), and the ridgetops east and west of Yellowjacket Canyon in the northern half of the field. Early maps of the Four Corners area indicate trails predating A.D. 1900 along

McElmo Creek and in the vicinity of the Yellowjacket Ruin, parallel to modern U.S. Highway 666. It is possible that these routes were also used by the Anasazi and that further research could result in their discovery.

After abandonment by the Anasazi culture, the McElmo Dome Field once again became the province of foraging nomadic groups. During the Shoshonean-Athabascan Period (A.D. 1300-1800), two different tribal groups are believed to have been in the area. Escalante and Dominguez documented the presence of Ute peoples in the district by 1776; small bands of these Shoshoneans were probably within the area at some earlier time. Contemporary Navajo populations entered the district by A.D. 1850 and engaged in hunting, herding, and limited agriculture. Although no site with either a Ute or a Navajo component has been recorded within the McElmo Dome Field, small groups of these historic tribes probably sporadically visited, camped, and foraged in the field.

Historic Resources

Known historic events or occupations in the CO_2 well field vicinity consist of a Spanish expedition in the 1700s and several remnants of log cabins and related buildings. The Escalante-Dominguez Expedition passed through the Dolores River Canyon in 1776. The expedition's route indicates that it spent the night of August 14-15, 1776 just north of the Dolores River Ranch. Evidence shows that the expedition did not camp within the boundaries of the Doe Canyon Field, thus it is unlikely that evidence of its passage will ever be recorded.

Modern western populations began to settle in the Four Corners area in the Early Historic Period (A.D. 1880-1930). Settlement and ranching activities within the field itself probably began in the 1890s.

Early Anglo occupations have been recorded at two sites: an early 20th century habitation adjacent to Durham Spring Reservoir and an abandoned logging camp west of Log Cabin Spring. Early historic activity has also been recorded at Big Water Spring. Where debris from an early 20th century logging and hunting camp overlies a prehistoric component. An early 20th century homestead has also been recorded. The site includes a log cabin foundation, collapsed root cellar, corral, and associated trash; a prehistoric component is also present.

Additional historic places in the vicinity of the CO_2 well field can be found in the following documents:

- National Register of Historic Places, yearly update; Federal Register V. 44, N. 26, Tuesday February 6, 1979

- Colorado Inventory of Historic Sites

No known sites in Dolores or Montezuma counties presently listed on the National Register of Historic Places, eligible for the National Register, or listed in the Colorado Inventory are present in the CO_2 well field.

MAIN CO_2 PIPELINE

Archaeological Resources

About 675 recorded sites are known to exist within a 10-mile strip centering on the pipeline. This number reflects those sites located during previous archaeological surveys within the 10-mile strip rather than the actual intensity of prehistoric occupation of the area. The highest concentrations of recorded sites are Anasazi sites, which occur in the Colorado section of the pipeline and in Sandoval County, New Mexico. No sites are recorded in Texas within a 10-mile strip centered on the pipeline. At the present time, no recorded archaeological sites are located within the main CO_2 pipeline right-of-way.

After finalization of the proposed right-of-way and prior to issuance of the right-of-way a cultural resource survey would be conducted to locate previously unknown sites. Major prehistoric and historic periods which are represented within the 10-mile strip and may be encountered by the pipeline are described in the following discussion.

Paleoindian Period (10,000-6000 B.C.). The Paleoindian Period dates from late glacial and early post-glacial times. It was predominantly a hunting stage that exploited large migratory herbivores, most of which are now extinct. It is likely that these hunters also utilized and exploited available vegetal resources. Social structure during the period probably consisted of the nuclear family organized into highly mobile nomadic bands, the most efficient unit for hunting game and for foraging.

The Paleoindian Period can be divided into three phases or complexes: the Clovis or Llano Complex (circa 10,000-9000 B.C.), the Folsom Complex (9000-7000 B.C.), and the Plano Complex (circa 7000-5000 B.C.). Artifacts from this period are represented by the fauna and associated stone tool (lithics) assemblages, particularly projectile points, of the three complexes.

Sites attributable to the Paleoindian Period are located throughout the Southwest. Along the pipeline route, Paleoindian sites are most likely to be in the Rio Grande Valley and to the east. Paleoindian sites will most likely to be buried and may be visible during trenching activities and in disturbed areas such as plowed fields, blowouts, and arroyos. There may be no visible evidence of sites in undisturbed areas. Types of sites that can be expected are kill sites, campsites, lithic scatters, and isolated artifacts. Eighteen recorded Paleoindian sites are known to exist within a 10-mile strip centering on the pipeline.

Archaic Period (6000 B.C.-A.D. 450). By the late Pleistocene the Southwest saw a gradual withdrawal of the large game-hunting Paleoindian groups. This population movement corresponds with a significant climatic change (decrease in moisture) and the resulting migration of large game animals to a wetter climate.

Archaic cultures are generally characterized by the hunting of modern animal species and by a heavy reliance on wild plant foods (suggesting that economy was based on food gathering). Grinding stones and stone tools for processing vegetable foods came into common use. Artifacts from the period include a variety of projectile points and tools such as choppers, scraper planes, butchering tools, and hammer stones. The perishable artifacts include baskets, matting, nets, snares, sandals, cordage of both vegetable fiber and hair, fire drills, digging sticks, atlatls and darts, wooden clubs, woven fiber, fur robes, containers of skin, and bone tools. Types of habitation sites and the conditions in which they are found include the following: (1) seasonal procurement camps, most frequently located in dune areas; (2) hunting camps, associated with higher elevations (usually mesa tops and canyon heads); and (3) sheltered camps, probably seasonally occupied and usually located near a permanent water source. There appears to have been a population shift just before the end of the Archaic Period toward localities that would support an increasing and permanent population with a growing dependence on agriculture.

Most Archaic sites have been found in western and southeastern New Mexico. Archaic sites may be located at any point along the pipeline route but particularly in areas containing several wild food sources. Older Archaic sites are likely to be buried with more recent sites visible on the surface. Types of sites that may be expected are rock shelters, camps with and without shelters, and lithic scatters. Three recorded Archaic sites are known to exist in a 10-mile strip centering on the pipeline.

Formative Period (A.D. 450-1450). During the centuries beginning the Christian era, the Archaic Period in the Southwest shifted from a predominantly hunting and gathering subsistence base to an agricultural economy with a sedentary village life. This trend led to the eventual coalescence of population, the building of large multiple and single room houses, and the creation of ceremonial centers. Much of the study area was abandoned in the early 1300s, leaving population concentrated in northern New Mexico along the upper Rio Grande Valley.

Two major post-Archaic southwestern cultures arose in the project vicinity and could be encountered along the pipeline route: the Anasazi (A.D. 450-1300) from Colorado to central New Mexico, and the Mogollon (A.D. 600-1450) from central New Mexico into western Texas. A 10-mile strip centered on the pipeline contains 448 recorded Anasazi sites and 9 Mogollon sites.

Formative Period sites are most likely to be found west of the Sandia-Manzano Mountains. The pipeline is not likely to encounter large sites, but may encounter or come near small sites and may cross Anasazi roads, particularly near the Chaco area. Evidence of sites should be clearly visible on the surface. Types of sites that may be encountered are as follows:

- Northern study area: multiple-room surface structure structures of stone masonry or adobe with subterranean kivas; single-room semi-subterranean slab-lined structures; circular single-room surface structures of rock; pottery and lithic scatters.

- Southern study area: circular and rectangular, slab-lined or unlined pithouses; multiple-room surface or slightly semi-subterranean structures of stone masonry or stone and adobe; open camps; rock shelters; pottery and lithic scatters.

<u>Athabascan-Shoshonean Period (post-A.D. 1300-present)</u>. Though little archaeological documentation exists for the prehistoric occupation of the proposed project area after the abandonment, the Navajos and Utes were known to have occupied the area prior to its abandonment. These tribes were semi-nomadic herdsmen who lived and traveled in family clusters and relied only on limited agriculture. Little archaeological evidence of these peoples exist because of their nomadic traits. Sites most likely to be encountered are surface sites such as slight depressions encircled with rocks (tipi sites) and open camps. In areas where limited agriculture was practiced, adobe structures may be found Separate discussions are presented below for each of these cultural groups.

<u>Navajo Tradition (A.D. 1550-1775)</u>. The Navajos and their Athabascan-speaking relatives, the Apaches, arrived in the area about A.D. 1500. The bulk of data for the Navajo tradition period is from northwestern New Mexico in the Upper San Juan, Gobernador, Largo, Big Bead Mesa, and Chaco localities. The possibility of encountering historic Navajo sites in the La Plata drainage is enhanced near the pipeline route, where Navajos are recorded to have lived with the Utes in the late 1800s. Navajos were employed as herders on both the Mountain Ute and Southern Ute reservations in southern Colorado during this time, and in 1877 a number of Navajos were living with a band of Wiminuche Utes headed by the Chief Cabezon along the La Plata River just south of the Colorado-New Mexico state line. In New Mexico, 17 recorded Navajo sites are known to exist within a 10-mile strip centering on the pipeline.

<u>Ute Tradition (circa A.D. 1600-present)</u>. The proposed pipeline route and right-of-way passes through the present Southern Ute Indian Reservation just east of the boundary with the Mountain Ute Indian Reservation to the west. Although the date the Utes entered southwestern Colorado is not known, it probably postdates Anasazi abandonment

of the area. The earliest historic period reference to the Southern Utes was made by the Spanish in 1626. By the time of the Pueblo Indian Revolt of 1680, the Spanish and Utes had made a treaty and some Spanish had visited the area. It is generally accepted in the literature that although the Utes frequently ranged south of the San Juan River, the river served as the boundary between the Ute homelands established north of the river and the Navajo homelands to the south. Consequently, early Ute sites may well be encountered along the pipeline right-of-way. Little is known at present about the archaeology of early Ute campsites and other activity areas. No recorded Ute sites are known to exist within a 10-mile strip centering on the pipeline.

Historic Resources

The earliest Euro-American intrusions into the area traversed by the main CO_2 pipeline were made by Spanish exploration parties. The well known Escalante-Dominguez Expedition of 1776 crossed the pipeline route north of the town of Mancos, Colorado; however, known remains from these early ventures are limited. The Spanish explorers who entered New Mexico in 1541 and again in the late 1590s remained in the Rio Grande valley. Physical evidence of Spanish occupation is found in the pueblo towns, Santa Fe, Albuquerque, Santa Clara, and various outlying town sites in the Rio Arriba country. Santa Fe, Bernalillo, Sandoval, Rio Arriba, and Taos counties represent this settlement.

In Colorado, Hispanos began settlement of La Plata and Montezuma counties by about 1880; Fort Lewis was constructed during that year to protect Euro-American settlers in the project area from the then-hostile Utes. The fort was located about 12 miles west of the town of Durango and about 5 miles east of the proposed pipeline. It was abandoned in 1891 by the U.S. Army, and fort buildings were transformed into an Indian School. Angry Indian children burned many of the buildings in 1892; in 1911 the Fort Lewis Military Reservation and Indian School was granted to the state of Colorado as part of the land-grant college system.

The Mexican government controlled New Mexico from 1821 to 1846, the period during which the Santa Fe Trail trade was developed between Missouri and Santa Fe. The trail, evidence of which is still visible, will not be affected by the proposed action. After American acquisition of New Mexico in 1846, trade lines were developed from Texas and Arizona. The Civil War intervened in development and several forts were constructed on the eastern plains to aid in the defense of the territory both on the part of the Union and the Confederacy. After the Civil War, Texas cattlemen overran the Llano Estacado of New Mexico and the cattle industry became the mainstay of the area. Physical evidence of this can be found in the form of ranches, line shacks, windmills, and trails. The famous Goodknight-Loving Cattle Trail would be intersected by the proposed pipeline. Small towns such as Lovington and Roswell served as "service centers" for this Texas cattle domain.

The turn of the century found Colorado, New Mexico, and Texas engaged in ranching, mining and agricultural pursuits.

No known sites in Texas are affected by the Main CO_2 pipeline.

OIL FIELD

No cultural resources have been recorded in the oil field or its vicinity. The Eastern Branch of the Jornada Mogollan inhabited southwestern Texas from about A.D. 950 to 1450, but evidence of this cultural group has not been found in the oil field. No known sites in Yoakum County presently listed on the National Register of Historic Places, eligible for the National Register, or listed in the Texas Inventory are present in the existing oil field.

VISUAL RESOURCES

A variety of distinct landscapes related to the Colorado Plateau, Basin and Range, and Great Plains physiographic provinces are present in the vicinity of the proposed CO_2 project. The BLM Visual Resource Management (VRM) system, on which this section is based, divides the landscape into VRM units. Management standards have been established to determine a permissible degree of landscape modification for each class. A detailed discussion of the assumptions and methodology used here and an explanation of the BLM Visual Resource Management System are presented in Appendix C.

Briefly, the BLM class definitions used in this discussion are:

- Class I: Primarily provides for natural ecological changes; management activities should be restricted and should not attract attention.
- Class II: Changes in the basic elements caused by management activities should not be evident in the characteristic landscape.
- Class III: Contrasts to the basic elements may be evident and begin to attract attention, but should remain subordinate to the existing characteristic landscape.

- Class IV: Alterations may attract attention but should repeat the form, line, color, and texture elements of the characteristic landscape.

CO_2 WELL FIELD

Narraguinnep Canyon Natural Area is designated as Class I (Map 2-3). As an interim management measure, initial Wilderness Study Areas are also being administered as VRM Class I areas. Sand Canyon and Mt. Sheep Point in the Dolores Canyon are classified as potential Areas of Critical Environmental Concern (ACEC) and are being administered VRM Class II areas. The portion of the Dolores River nominated as Wild and Scenic is also designated as Class II.

Landscape Character

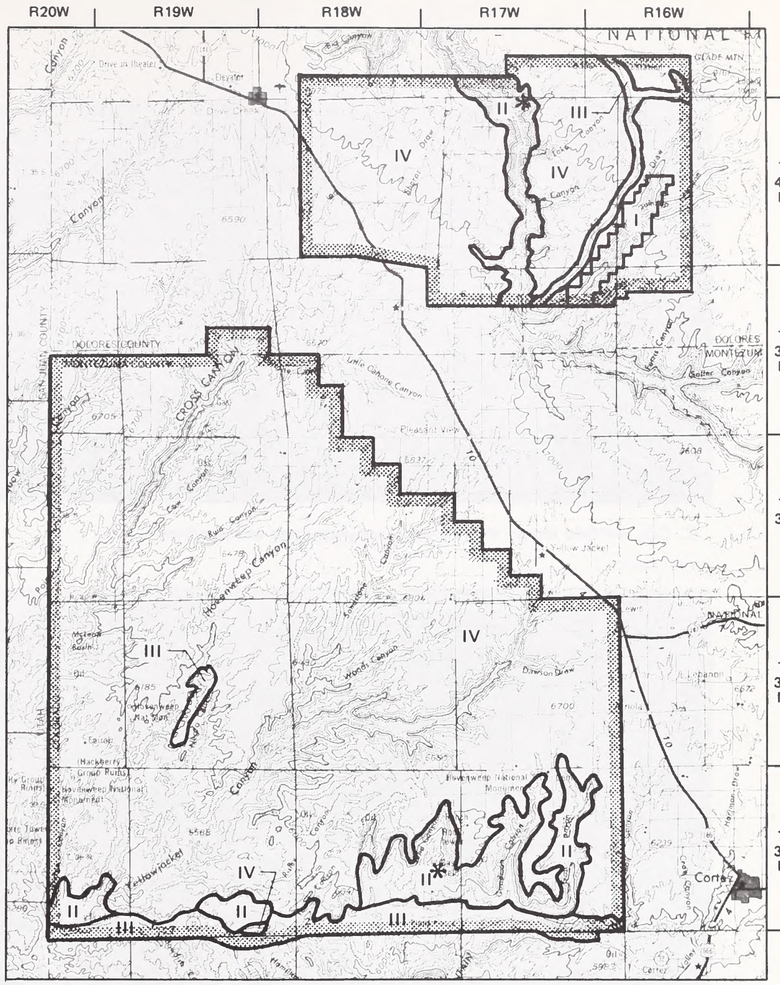
The landscape in the vicinity of the CO_2 well field is dominated by a combination of gently rolling mesa tops and canyons up to several hundred feet deep. Valleys and bottomlands are often quite narrow. McElmo Creek and the Dolores River are the only major perennial streams in the CO_2 well field.

The proposed dry-CO_2 pipeline crossing of the Dolores River passes through about one mile of Class II area (U.S. Forest Service [USFS] Category Modification). Dolores Canyon and the Dolores River crossing are dominated by contrasts between steep canyon walls, several wooded arroyos or draws, and changing vegetation on the canyon slopes and bottomland adjacent to the river. This contrast is accentuated seasonally during the fall when deciduous trees in the bottomland turn predominantly yellow and the juniper and pine trees on the slope remain a dark green.

Canyon walls vary in height and slope, and are generally roughly textured with frequent rock outcroppings and scattered pinyon, juniper, and ponderosa pine trees, and Gambel oak. In contrast, the mesa tops are generally a mosaic of cropland, grazing land, and timber land, usually identified as VRM Class IV. Light colored surface rock outcrop and vegetation growing along the washes blend into the background when viewed from a short distance. Distant mountain peaks are visible on most horizons (Figure 2-3).

MAIN CO_2 PIPELINE

Approximately 65 percent of the land along the proposed main CO_2 pipeline route is classified as VRM Class IV (Figure 2-4). About 22 percent of the proposed route is in VRM Class III, 7 percent in Class II, and 3 percent in Class I. About 3 percent of the proposed route passes through Indian lands which are not classified under the BLM system.



Source: U.S. Bureau of Land Management 1979b; U.S. Forest Service 1979

LEGEND

CO_2 Well Field Boundary

I-IV Classification and Boundary

* Area of Critical Environmental Concern

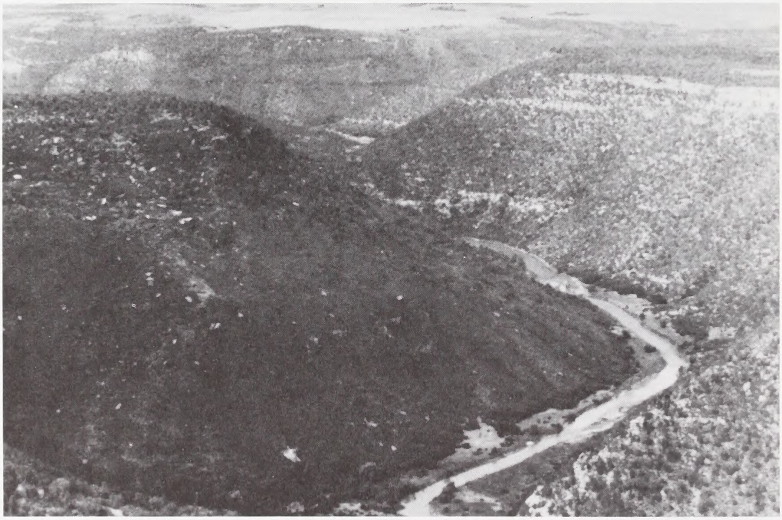
N

0 3 6

miles

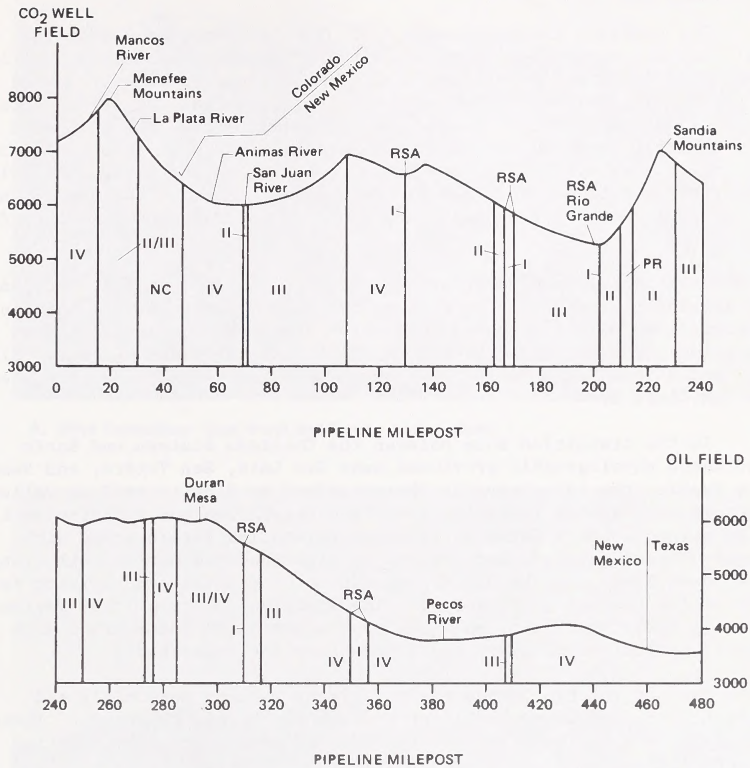
Map 2-3. VISUAL RESOURCE MANAGEMENT (VRM) CLASSIFICATIONS FOR THE CO_2 WELL FIELD

A. CO_2 wellfield terrain showing mosaic of agriculture and woodland



B. Dolores River Canyon

Figure 2-3. COLORADO PLATEAU PHYSIOGRAPHIC REGION



LEGEND

I, II, III, IV – Visual Resource Management Classes
RSA – Roadless Study Area
PR – Partial Retention (U.S. Forest Service Classification)
NC – No Classification (Southern Ute. Indian Reservation)

Figure 2-4. VISUAL RESOURCE MANAGEMENT CLASSIFICATIONS ALONG THE PIPELINE ROUTE

Landscape Character

The dominant landscape on the Colorado Plateau, from near the Colorado-New Mexico border to the Farmington area, consists of rolling mesa grasslands and occasional dark rock outcrops cut by flat, wide arroyos. The Animas River floodplain is mostly flat and grades into the foothill grasslands near Blanco, east of Farmington. The irrigated agricultural lands on the floodplain create variety in color and texture to the landscape. The greyish green, coarse-textured grasslands join the irrigated lands along the San Juan River. Most of the area along this section of the proposed route from the Colorado-New Mexico border is in VRM Class IV.

Rolling hills and scattered sagebrush, saltbush, greasewood, and grasslands characterize the region from Blanco Canyon to San Luis in the vicinity of the proposed compressor station. The level horizon is occasionally interrupted by the vertical walls of distant mesas. Slight variation in color or texture of vegetation and soils place this area in VRM Class IV.

In the transition zone between the Colorado Plateau and Basin and Range physiographic provinces near San Luis, San Ysidro, and Santa Ana Pueblo, the topography is characterized by flat to rolling valley bottoms with sparse irregular grassland vegetation cut by infrequent wide arroyos. Dark bands of riparian vegetation interspersed with sagebrush and juniper, and patches of light-colored barren soil along the Jemez River and the Rio Grande add color contrast and texture to the valley bottoms (Figure 2-5). The dominant colors of this region are the red, tan, brown, and grey of the soils and rocks mixed with subtle variations of greys and greens from the vegetation.

East of the Rio Grande the topography becomes more hilly and abruptly rises 4000 to 5000 feet to form the Sandia Mountains. These mountains are characterized by a series of steep, angular mountain peaks with jagged edges of massive rock outcroppings (Figure 2-6). Canyons and washes are present on the sides of the mountain. Varying densities of juniper on the mid-level slopes and scattered boulders create an overall rough texture. This region contains VRM Class II and III areas depending on the variety of landforms and vegetation.

The topography changes from the gentle eastern slopes of the Sandia Mountains to the rolling foothills and flat terrain of the agricultural lands near Moriarty. The landscape southeast of Moriarty to the oil field in Texas is generally composed of nearly flat to gently rolling hills and grasslands characteristic of the Great Plains (Figure 2-7). The plains landscape is occasionally interrupted by arroyos and a few mesas such as the mesa near Duran. Some contrast to the dull greyish-green color of the vegetation is provided by the white walls of limestone sinkholes, reddish soil, or patches of light-colored sandy soil. Vegetation is dominated by grasses with some clusters of juniper trees that appear as a dark band in contrast. The riparian

A. Mesa Vegetation— Sage Brush and Pinyon Juniper Cover

B. Mesa formations in San Juan Basin area

Figure 2-5. COLORADO PLATEAU PHYSIOGRAPHIC REGION

A. Rio Grande in foreground showing band of riparian vegetation

B. Representative terrain Sandia Mountains (view from base)

Figure 2-6. BASIN AND RANGE PHYSIOGRAPHIC REGION

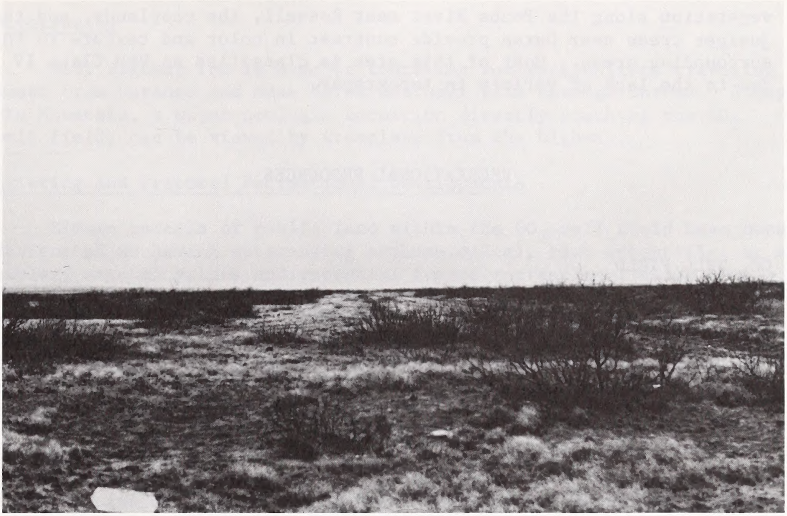


Figure 2-7. PLAINS REGION NEAR ROSWELL, NEW MEXICO

vegetation along the Pecos River near Roswell, the croplands, and the juniper trees near Duran provide contrast in color and texture to the surrounding areas. Most of this area is classified as VRM Class IV due to the lack of variety in topography.

RECREATIONAL RESOURCES

CO_2 WELL FIELD

Approximately 145,300 of 330,000 acres in the CO_2 well field are administered by the BLM and the U.S. Forest Service (USFS). These lands provide numerous scientific, educational, and recreational opportunities based primarily upon the area's many archaeological resources. These resources are considered nationally significant and their value is expected to grow as public awareness and demand increase.

Hunting/Fishing

Big game hunting is limited to mule deer, which range over the entire CO_2 well field except for the southern edge, and elk, which are confined to the Dolores River area. Demand for big game hunting on public lands in the CO_2 well field has continued to increase while habitat and numbers have declined primarily due to the conversion of pinyon-juniper woodlands into agricultural lands. Small game hunting (small mammals, waterfowl, and upland game birds) is currently not considered a major pastime.

In 1976 there were an estimated 10,256 recreation days of deer hunting in Dolores County and 9,454 in Montezuma County. A substantial amount of this use was by non-residents. In addition, Dolores County had 16,164 recreation days of elk hunting and 1,057 recreation days of black bear hunting. In Montezuma County there were 9,217 and 1,046 recreation days of elk and black bear hunting, respectively. In the CO_2 well field counties, areas inhabited by deer and elk populations are accessible from U.S. Highway 666, State Highways 145 and 150, and various forest service roads.

Fishing in the CO_2 well field is confined to McElmo and Yellow-jacket creeks and the Dolores River. Insufficient streamflow, poor quality aquatic habitat, and limited populations of game species have restricted fishing activities in the region.

Sightseeing

U.S. Highway 160 is a major route for recreationalists traveling south from Durango and Mesa Verde National Park through Cortez. Sleeping Ute Mountain, a major geologic formation directly south of the CO_2 well field, can be viewed by travelers from the highway.

Existing and Proposed Recreational Developments

Eleven parcels of public land within the CO_2 well field have been designated as having outstanding archaeological, rare scientific, or exemplary natural values and potential future recreational value (Table 2-14). These areas are subject to special land management practices under genuine public land laws for protection of outstanding resources. Conversion to any use not directly related to or incompatible with the area's particular public purpose or program is prohibited. These areas are either entirely closed to mineral leasing or leased with a "no surface occupancy" stipulation.

Lowry Ruins National Historic Landmark (administered by the BLM) and Hovenweep National Monument (administered by the National Park Service) are two of a large number of archaeologic sites on public lands within the CO_2 well field. These sites have been excavated and stabilized, and consist of several large Anasazi Indian pueblos (habitation sites) and towers. Picnicking, toilet, and parking facilities are provided; however, some of the ruins are isolated and difficult to reach. In 1978 Lowry Ruins received over 2000 visitors while 17,548 people visited Hovenweep National Monument. Of these, 3410 visited the separated units of the monument in closest proximity to the CO_2 well field. Developed recreation sites near the CO_2 well field include Mesa Verde National Park (administered by National Park Service) and Escalante Ruins National Monument (administered by BLM). Mesa Verde contains well preserved prehistoric cliff dwellings, protected wildlife, and undisturbed vegetation. Annual visitor use is in excess of 615,000 days.

BLM is reviewing much of the CO_2 well field region as either a potential National Heritage Conservation District or a proposed National Recreational Area (McElmo Anasazi Recreational Area) to help alleviate overcrowded conditions in Mesa Verde National Park. Examples of major sites or complexes would be excavated and stabilized with approval of these proposals. Road networks would lead to each complex and a system of trails would connect and provide access to smaller sites of significance surrounding each complex. Existing compatible uses (e.g., grazing, wildlife habitat) would be allowed to continue, and mining would be permitted on a case-by-case basis and prohibited in critical areas.

Portions of the Dolores River and abutting land (a corridor approximately 1/4 mile wide on each side of the river) have been proposed for inclusion in the National Wild and Scenic River System. Inclusion of the river in the national system would provide public recreation and statutory protection as well as preservation of the river's national and

Table 2-14. RESOURCE AREAS WITH SIGNIFICANT SCIENTIFIC, NATURAL OR RECREATIONAL VALUE WITHIN THE CO_2 FIELD

Site	Administrative Agency	Location within Well Field Region	Approximate Total Acreage	Protective Legislation	Description
Lowry Ruins National Historic Landmark	BLM	9 miles west of U.S. Highway 666 at Pleasant View	80	Public Land Order (PLO) 3843	Anasazi large habitation site (pueblo) with great kiva*
Hovenweep National Monument (Holly, Hackberry, Goodman Point Canyon, and Cutthroat Castle)	National Park Service	8 and 24 miles northwest of Cortez	784	Historic Sites Act of 1935	Numerous Anasazi towers and pueblos*
McLean Basin Towers	BLM	3 miles northwest of Hovenweep National Monument	80	PLO 3843	Several Anasazi towers with distinct markings
Picture Rock	BLM	17 miles northwest of Cortez	120	PLO 3843	Indian pueblo petroglyphs and pictographs
Rare snake and lizard area	BLM	Adjacent to the Colorado-Utah state line about 28 miles west of Cortez	480	PLO 3701	Rare reptilian habitat area
Cannon Ball Mesa Ruin	BLM	22 miles southwest of Cortez	80	PLO 3843	Indian ruins and petroglyphs
Easter Ruins	BLM	6 miles southwest of Lewis	80	PLO 3843	Surface pueblo ruin
Sand Canyon	BLM	12 miles west of Cortez	4543	PLO 3843	Outstanding cliff dwellings and associated pueblo sites
Negro Canyon	BLM	20 miles northwest of Cortez	40	PLO 3843	Clustering of several large ruins
Naraguinnep Natural Area	USFS	6 miles east of Cahone	4079	Executive Order 10355	Exemplary Ponderosa pine ecosystem
Dolores River	BLM-USFS	San Juan National Forest	3200**	Wild and Scenic Rivers Act (PLO 90-542)	Proposed Wild and Scenic River

*Also see discussion in text.
**1/2-mile wide corridor centered on Dolores River through well field region.

scenic values (see Appendix F, Map F-1). Uses such as mining, timber harvesting, and grazing would continue under certain conditions of the various river use classifications (wild, scenic, recreational). Approximately 10 miles of the river flows through the CO_2 well field; this segment has been nominated for "scenic" river designation and must be free of impoundments, be accessible in places by road, have watersheds still largely primitive, and have generally undeveloped shorelines (USFS 1976). Under this designation the river could continue to be used for recreational rafting and boating. This activity is especially popular during spring runoff from the middle of April to the end of June. Earlier use is discouraged by low air and water temperatures; later use is discouraged by subsiding runoff. In 1976, there were an estimated 3200 boater days of recreation use on the river.

MAIN CO_2 PIPELINE

About 205 of the 478 miles of land crossed by the proposed pipeline is administered by federal agencies (see Appendix F, Maps F-2 through F-11). The BLM administers approximately 119 miles of the land traversed and the remainder is managed by the Bureau of Indian Affairs (81 miles) or USFS (5 miles). Recreational opportunities are expected in varying degrees throughout the public lands along the route; these may be broadly described as "extensive" or "dispersed" (i.e., no distinct recreational facilities are provided). Common recreational activities include rock hounding, wildlife observation, archaeological study, off-road vehicle (ORV) use, caving, picnicking, camping, and hiking.

Hunting/Fishing

Virtually all of the area along the pipeline route is range for some type of big game, including mule deer, antelope, bear, turkey, and other species. Mule deer and antelope provide the most significant big game hunting. Waterfowl hunting and fishing are primarily limited to the major rivers, including the San Juan, Rio Grande, and Pecos rivers. Total numbers of hunters and recreation days in the pipeline vicinity are not known.

Sightseeing/Historical Interest

Sightseeing along the pipeline route is oriented primarily toward the attraction of wildlife, geologic features, and historic sites. Many of the major highways along the route provide ample opportunities for viewing scenic resources (see Chapter 2, Visual Resources, for major viewsheds along the pipeline route).

Existing Recreation Developments

Recreational developments along the pipeline route are limited. Table 2-15 lists the eight existing developed recreational facilities within 5 miles of the pipeline right-of-way.

Table 2-15. EXISTING RECREATION DEVELOPMENTS WITHIN FIVE MILES OF THE PROPOSED PIPELINE ROUTE

Site	Administrative Agency	Approximate Total Acreage	Approximate Distance from Pipeline	Location (County)	Description
Mountain Ute Mancos Canyon Historic District	BIA	208,000	.5	Montezuma, La Plata, CO	Anasazi Indian ruins
Aztec Ruins National Monument	National Park Service	51,334	4	Montezuma, CO	Prehistoric Anasazi Indian cliff dwellings
Chaco Canyon National Monument	National Park Service	21,509	5	McKinley, NM	Major center of Pueblo Indian culture
Tamaya (Santa Ana Pueblo)	BIA	NA	.5	Sandoval, NM	Existing Pueblo Indian site
Zia Pueblo	BIA	NA	1	Sandoval, NM	Existing Pueblo Indian site
Sandia Cave Historic Landmark	USFS	NA	2	Bernalillo, NM	Historic Indian cave site
Salt Creek Wilderness	Fish and Wildlife Service	9,621	1.5	Chaves, NM	Sanctuary for migratory water-flow and sandhill cranes
Inkpot Research Natural Area*	Fish and Wildlife Service	2	4	Chaves, NM	Fragile marine wildlife habitat area

BIA = Bureau of Indian Affairs.
NA = Not available.
*Located within Salt Creek Wilderness.

Off-Road Vehicle Use

ORV use of public lands along the pipeline route is restricted to designated areas, but also takes place on private lands. It generally occurs in conjunction with other activities (e.g., hunting, fishing, sightseeing) on overland trails and tracks. Concentrated ORV use on lands has caused damage to natural resources in some areas (soil compaction and vegetation destruction) and disrupted less intensive recreation uses.

AGRICULTURAL RESOURCES

CO_2 WELL FIELD

Livestock Grazing

Cattle and sheep grazing is the predominant land use in the CO_2 well field. Approximately 250,000 acres of land within the CO_2 well field are used for rangeland. Many public lands have been divided into grazing allotments (geographic units) currently grazed under permit or leased to local ranchers. These allotments provide approximately 15,000 to 20,000 animal unit months (AUMs) per year for livestock (one AUM is equal to the forage required to support one cow and calf, one horse, or five sheep or goats for one month). Use of the range may be either seasonal or yearly, depending on the management system established on the specific allotment. Allotment Management Plans (AMPs), which prescribe some form of pasture rotation grazing system and necessary range improvements, have been developed for most grazing allotments in the CO_2 well field.

Approximately 22,000 acres of pinyon-juniper woodland vegetation in the CO_2 well field have been chained and seeded to improve herbage production and to increase grazing capacities. Effectiveness of the chaining treatment has varied, depending upon type of treatment, soil type, and subsequent management and maintenance.

Farmland

Dryland agriculture (primarily pinto beans and winter wheat) are produced on approximately 55,800 acres within the well field. Crops are generally grown on the mesa and plateau tops; steep, sloping topography limits significant increases in acreage. Approximately 5500 acres within the well field are presently irrigated, generally in the canyon valleys and along McElmo Creek. Development of the Dolores Project will convert approximately 4000 acres of dry farmland and approximately 450 acres of grazing land to irrigated farmland within the CO_2 well field.

Table 2-16. FARMLAND WITHIN PIPELINE RIGHT-OF-WAY

County	MP	Irrigated Agriculture		Dryland Agriculture		Total Agri-culture
		Linear miles	Acres within pipeline right-of-way	Linear miles	Acres within pipeline right-of-way	(Acres)
Montezuma, CO	0-20	-	-	6	70	70
La Plata, CO	20-46	-	-	6	70	70
San Juan, NM	46-121	3	30	-	-	30
Sandoval, NM	144-219	2	25	-	-	25
Bernalillo, NM	219-228	-	-	4	50	50
Torrance, NM	235-304	7	85	3	40	125
Yoakum, TX	462-478	-	-	1	20	20
TOTAL		12	140	20	250	390

Source: Based on Technology Application Center 1977.

Forestry

About 27,000 acres of forest resources exist within the CO_2 well field. Timbered areas presently harvested are second growth Ponderosa pine stands (on U.S. Forest Service [USFS] lands) and other trees with insect or disease damage. Stands on USFS lands within the CO_2 well field contain an estimated 146 million board feet. Small, scattered ponderosa pine stands on BLM lands and old growth stands on USFS lands are generally managed as protective stands because of overall low site quality, excessive slopes, rocky terrain, small acreages, low volume, and low regeneration potential. These and other woodland areas (primarily 171,700 acres of pinyon-juniper) presently have limited commercial value (firewood and post sales) and are considered more important for other uses (grazing, wildlife habitat, and recreation) than for wood fiber.

MAIN CO_2 PIPELINE

Livestock Grazing

As the area's predominant land use activity, grazing occurs on about 90 percent of the land along the pipeline route, on nearly all the grasslands and lowland areas as well as at upper elevations (outside Albuquerque, New Mexico in the Sandia Mountains). Three categories of rangeland are present along the main CO_2 pipeline right-of-way:

- Rangeland 1 (primarily desert grasslands)
- Rangeland 2 (primarily desert shrub and sagebrush)
- Woodland (primarily pinyon-juniper)

Approximately 3000 acres total rangeland is under private ownership. About 2400 acres are administered by federal agencies and grazed under lease or license to local livestock operators. Grazing use is expressed in AUMs based on estimated forage carrying capacity, and varies widely due to the diversity of vegetation, soil types, climatic conditions, and level of management. There are an estimated 750 AUMs within the proposed right-of-way.

Farmland

Farmland has been subdivided into irrigated agriculture and dryland agriculture. The proposed pipeline would cross approximately 12 miles of irrigated farmland and 20 miles of dry farmland in seven counties (Table 2-16). This farmland represents approximately 7 percent of the land along the pipeline route. Irrigated agriculture is concentrated along the major perennial streams. Hay and other livestock feed for local livestock industry needs are the major crops raised within the irrigated river valleys. Many of the dryland areas are also currently used to produce livestock feed.

Forestry

The proposed pipeline would cross no areas where forest products are commercially harvested. Forested areas along the pipeline route are currently used to a large extent for recreation and grazing.

WILDERNESS VALUES

CO_2 WELL FIELD

Approximately 34,800 acres of public land within the proposed CO_2 well field area have been preliminarily identified by the BLM for potential wilderness review pursuant to Section 603 of the Federal Land Policy and Management Act (FLPMA) of 1976. These areas are subject to interim management to protect wilderness values until a final wilderness determination is made by Congress. Prior to final determination, multiple-use activities (including mineral leasing and access) would be allowed with advance planning to prevent undue degradation of these designated areas. New uses can be approved if an environmental assessment record (EAR) or environmental statement (ES) on the proposed action shows that the impacts would not impair suitability of the area for wilderness. Environmental controls or modifications (such as design, rehabilitation, or limitations on location and length of use) may be applied to protect wilderness values and roadless characteristics.

MAIN CO_2 PIPELINE

Both USFS (pursuant to the Wilderness Act of 1964) and BLM (in response to Section 603 of FLPMA) have identified areas along the pipeline route for potential wilderness review. These areas are subject to interim management to protect wilderness values until a final management recommendation is made by Congress. Prior to final determination, multiple-use activities are allowed with advance planning for prevention of undue degradation of these designated areas. New uses (such as the proposed pipeline right-of-way) can be approved if an ES on the proposed action shows that the impacts would not impair suitability of the area for wilderness. Environmental controls or modifications (such as design, rehabilitation, or limitations on location and length of use) may be applied to protect wilderness areas.

MINERAL RESOURCES

CO_2 WELL FIELD

The proposed CO_2 well field contain deposits of uranium, coal, and sodium in the underlying strata. Deposits of uranium ore are known to exit in the Morrison formation; many uranium claims exist within the proposed CO_2 well fields. The deposits are not being mined at present. They are not presently commercially available with current technology. Coal exists in the Dakota formation; commercial quantities exist east of the proposed CO_2 well field. No commercial coal deposits are known to exist within the well field boundaries. Sodium exists in the paradox salt; no active development within the well field boundaries is anticipated. Any future exploration or development of these minerals would not be inhibited by the proposed action.

CO_2 PIPELINE

The proposed main CO_2 pipeline route crosses an area of commercially strippable coal (BLM, 1978c) between Farmington and Cuba in northwestern New Mexico. The coal exists in the Fruitland Formation, and varies in thickness from 10 to 70 feet. Most of the coal under the proposed route averages 30 to 40 feet in thickness.

TRANSPORTATION NETWORKS

CO_2 WELL FIELD

The major access to the CO_2 well field is via U.S. Route 666 which traverses the well fields for an approximate total distance of 5 miles. Other paved roads in the CO_2 well field include Pleasant View Road, which roughly bisects the McElmo Dome Field, and McElmo Creek Road, which runs along the southern boundary of the McElmo Dome Field. Access to the eastern portion of the Doe Canyon Field is via either the bridge across the Dolores River east of Cahone or a road along the bottom of the Dolores Canyon. Several other maintained roads and unmaintained jeep trails also provide limited access. These roads are frequently impassable during or following storms, and lack signs, which discourages use by the general public unfamiliar with local conditions.

MAIN CO_2 PIPELINE

Principal primary and secondary roads which would be crossed by the proposed pipeline are listed in Table 2-17. The proposed pipeline route crosses 25 roads. Traffic volumes on 12 of these roads are generally less than 1000 vehicles per day. The pipeline would also cross 14 state highways, 9 U.S. highways, and two interstate highways (Interstates 25 and 40). Traffic volumes on five of these roads are greater than 3000 vehicles per day. The proposed route intersects railroads at six locations.

SOCIOECONOMICS

This section describes existing socioeconomic conditions of the 15 counties in which the proposed CO_2 project would be located (see Map 1-1). Only those social or economic characteristics relevant to the assessment of impacts presented in Chapter 3, Socioeconomics are discussed; these include population, economy, primary (public) services, selected secondary (private) services, and fiscal status.

CO_2 WELL FIELD

Population

The towns of Dove Creek (Dolores County) and Cortez (Montezuma County) lie immediately adjacent to the proposed CO_2 well field in Colorado. These towns and counties grew rapidly from 1950 to 1960 as a result of substantial in-migration brought about by sudden increases in oil and uranium exploration (Table 2-18). A sharp decline in mineral exploration led to an overall regional population decrease between 1960 and 1970, followed by a population increase in the two counties from 1970 to present. Most of the growth has occurred in Cortez, the population center of the two-county area and service center for the Four Corners area. A sizable portion of the population lives in rural, unincorporated areas of both counties, mainly in the irrigated areas of Montezuma County near Cortez and along U.S. Highway 160 between Cortez and Dove Creek.

Potential "boom town" condition is commonly defined as an annual population growth of 5 percent or more; none of the towns in the vicinity of the CO_2 well field is currently experiencing such growth. The annual rate of growth for Cortez between 1970 and 1975 was less than 2 percent; the rate for the city of Dolores was less than 3 percent. A census performed in Cortez in summer 1978 showed that earlier population projections were not being realized; preliminary tabulations suggest a population count of 7100 to 7200.

Table 2-17. MAIN CO_2 PIPELINE HIGHWAY AND RAILROAD CROSSINGS

Description	County/State	Approximate Milepost	Daily Traffic Volume (Vehicles/24 hrs)
SH 184	Montezuma, CO	13.0	430
US 160	Montezuma, CO	15.5	3150
SH 140	La Plata, CO	36.0	440
US 550	San Juan, NM	59.0	4050
RR[a]	San Juan, NM	59.0	–
US 64	San Juan, NM	71.1	*
SH 44	San Juan, NM	106.8	2780
SH 197	Sandoval, NM	151.0	*
SH 44	Sandoval, NM	190.5	3580
US 85	Sandoval, NM	204.0	*
RR[b]	Sandoval, NM	204.0	–
I 25	Sandoval, NM	204.5	12840
SH 14(10)	Bernalillo, NM	222.0	*
I 40	Sante Fe, NM	233.7	9950
RR[b]	Torrance, NM	243.0	–
SH 41	Torrance, NM	243.0	1270
US 60	Torrance, NM	272.0	430
RR[b]	Torrance, NM	276.0	–
RR[c]	Torrance, NM	294.5	–
US 54	Torrance, NM	299.0	705
SH 42	Lincoln, NM	325.0	*
US 285	Chaves, NM	365.0	1420
US 70	Chaves, NM	383.2	2365
RR[b]	Chaves, NM	385.7	–
US 380	Chaves, NM	415.5	990
SH 172	Chaves, NM	417.0	110
SH 457	Lea, NM	430.0	*
SH 18	Lea, NM	445.2	1800
SH 769	Yoakum, TX	462.0	*
US 82	Yoakum, TX	463.5	1606
SH 214	Yoakum, TX	477.0	*

[a]Denver and Rio Grande Western Railroad.
[b]Atchison Topeka and Santa Fe Railroad.
[c]Southern Pacific Railroad.
*Traffic data not readily available; traffic volumes on these roads are assumed to be generally small (less than 500 vehicles/24 hrs).
Note: SH = state highway.
US = U.S. highway.
RR = railroad.

Table 2-18. POPULATION IN THE TWO-COUNTY (MONTEZUMA AND DOLORES) CO_2 WELL FIELD AREA (1950 to 1975)

	1950	1960	% change 1950-1960	1970	% change 1960-1970	1973	1975	% change 1970-1975
Montezuma County	9,991	14,024	40.4	12,952	-7.6	13,799	14,950	15.4
Cortez	2,680	6,764	152.4	6,032	-10.8	6,275	6,793	12.6
Dolores	729	805	10.4	820	1.9	859	946	15.4
Mancos				709		802	974	13.1
Dolores County	1,966	2,196	11.7	1,641	-25.3	1,641	1,682	2.5
Dove Creek	702	986	40.5	619	-37.2	672	736	18.9
TOTAL	11,957	16,220	35.7	14,593	-10.0	15,440	16,632	14.0

Source: U.S. Bureau of the Census 1977a.

Population projections for the area assume a high level of energy related development, an increase in tourist and retirement related activities, and development of the Dolores Project. Much of this growth will occur in Cortez, which is located adjacent to Mesa Verde National Park. To manage this growth, the state of Colorado has allowed Cortez to administer a wide range of land use controls within city limits. Cortez currently practices comprehensive land use planning and administers direct control through techniques such as zoning, subdivision regulation, and use permits. The city may also exercise limited regulation of subdivision development of unincorporated areas as far as 3 miles beyond city limits. Under a plan adopted in 1978, the city uses the concept of overlapping zones, which allows flexibility and responsiveness in growth management.

Economy

Agriculture historically has been the major economic activity in the vicinity of the CO_2 well field. The major crops are beans, grain, and silage. Timber production and energy minerals extraction have recently become established activities.

Montezuma County's employment growth between 1970 and 1976 is of particular relevance to the proposed project in trade, mining, and services (Table 2-19). Increased employment in wholesale and retail trade and service is consistent with population growth and increasing tourism in this region during the period.

In contrast to the growth in Montezuma County, the primarily non-agricultural work force in Dolores County declined between 1970 and 1976 (Table 2-19). Trade and public services particularly were affected by this decline; losses to both of these sectors are consistent with the lack of population growth in the county.

Primary and Secondary Services

Primary, or public, services for the area including schools, hospitals, police and fire services, air service, and public utilities are adequately provided in the population center of Cortez. Dove Creek and Cortez both maintain complete educational services (elementary, junior, and senior high schools), full-time law enforcement, and sizable fire departments (more than 4 pieces of equipment and 20 volunteers each). Health care services are provided at Southwest Memorial Hospital in Cortez, a general, short-term care facility with 84 beds and a full-time staff of 23 nurses. Both towns have gas, electric, water, and sewage services as well as solid-waste disposal sites.

Most public services in and around Cortez have increased with recent increases in demand; however, sewer treatment facilities in a prime growth area of the city is currently at capacity. Application has been made to the EPA for funds to double sewer capacity in this area. This

Table 2-19. NON-AGRICULTURAL EMPLOYMENT BY INDUSTRY IN DOLORES AND MONTEZUMA COUNTIES, 1970-1976

	1970	1972	1974	1976
DOLORES				
Total	293	308	112	142
Contract construction	0	D*	0	0-19
Agricultural services, forestry, fisheries	0	0	0	0
Mining	D	D	20-99	20-99
Manufacturing	0	0	0	0
Transportation and other public services	49	43	0-19	7
Wholesale trade	32	57	32	34
Retail trade	122	141	37	57
Finance, insurance, and real estate	D	D	0-19	0-19
Services	D	D	0-19	0-19
MONTEZUMA				
Total	2156	2667	3240	2912
Contract construction	143	211	265	250
Agricultural services, forestry, fisheries	D	D	0-19	0-19
Mining	173	310	250-499	250-499
Manufacturing	362	456	510	289
Transportation and other public services	150	118	145	211
Wholesale trade	105	103	231	279
Retail trade	673	728	845	950
Finance, insurance, and real estate	85	95	100-249	100-249
Services	416	591	581	502

* D = figures withheld to avoid disclosure of operations of individual establishments.

Source: U.S. Bureau of the Census 1971l, 1973b, 1975, 1977b.

Table 2-20. SCHOOL ENROLLMENTS FOR MONTEZUMA COUNTY, (1970, 1975, 1978)

District	1970	1975	1978
Re 1	x	2982	2998
Re 4A	x	532	536
Re 6	x	440	444
TOTAL	3804	3954	2978

Sources: Office of Adminsitration, Re 1; Office of the Superintendent, Re 4A; Office of the Superintendent, Re 6; City/County Data Book 1977.

application has passed Phase I of the EPA process; a decision on Phase II is due in October 1979.

Adequate capacity in area schools has been maintained. During the period from 1970 to 1975, Montezuma County schools witnessed a slight increase in enrollments (3.9%) (Table 2-20). Unlike the nationwide trend of decreasing school enrollments, district enrollment figures for Montezuma County show enrollment has remained stable for the period from 1975 to 1978.

Secondary, or privately, provided services include motel facilities, housing, and trade establishments (e.g., grocery, pharmacy). Though housing availability is limited in the vicinity, it has recently shown signs of improvement; other private services have been able to expand in response to increasing demand.

There are 750 hotel-motel beds in Cortez which commonly operate near capacity from June 1 to September 1, then drop to 40 percent use for the balance of the year.

The majority of trade establishments and service organizations are located in the vicinity of Cortez. These trade establishments include more than 16 motels and diverse restaurant facilities which include fast food drive-ins, coffee shops, and restaurants with banquet facilities. Dressmakers, self-service dry cleaners, grocers, and hardware retailers also trade in the area.

Between 1960 and 1970, Dolores County experienced a 30 percent decrease in the total number of housing units; Montezuma County suffered a 7 percent decrease. These declines in total number of housing units correspond with population declines during the same period. Also during this time, rental units dropped in proportion to housing units from 29 to 27 percent in Dolores County, but increased from 25 to 27 percent in Montezuma County (U.S. Bureau of the Census 1962, 1972).

Housing figures improved from 1970 to 1977 but continued to reveal a shortage of standard housing in the area (see Table 2-21). This shortage, coupled with rising costs for new home construction, led to a substantial increase in the number of mobile homes in the area. During the seven-year period, the number of mobile homes increased 51 percent in Dolores County and 121 percent in Montezuma County.

Although a shortage of lower priced housing continues, the last few years have brought a substantial increase in the availability of housing for sale and rent.* Trend data on new housing starts in Montezuma County are equally encouraging, showing a steady increase in housing being built (Table 2-22).

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*Personal communication with Cortez City Manager, February 1978.

Table 2-21. DISTRIBUTION OF DOLORES AND MONTEZUMA COUNTY HOUSING BY HOUSING TYPE (1970 and 1977)

	Montezuma County			Dolores County		
	1970	1977	% Change 1970-1972	1970	1977	% Change 1970-1977
Conventional Units	4045	4120	+ 1.9	591	581	- 1.7
Owner	2884	2994	- 3.8	417	412	- 1.2
Rental	1161	1126	+ 3.0	174	169	+ 2.9
Mobile Homes	357	790	+121.3	53	80	+50.9
Owner	303	670	+121.1	45	70	+55.6
Rental	54	120	+122.2	8	10	+25.0
Households	3965	5110	+ 28.9	500	560	+12.0

Source: Colorado Division of Housing 1978.

Table 2-22. ESTIMATED HOUSING STARTS IN MONTEZUMA COUNTY (1970 to 1976)

	1970	1972	1974	1976
Single	2	31	35	45
Duplex	0	0	0	10
Multiple	0	32	0	10
TOTAL	2	63	35	65

Source: Colorado Division of Housing 1978.

Dove Creek, like other towns along Highway 160, serves the small, local farming area and has less secondary facilities and services than Cortez.

Expectations and Lifestyles

Cortez serves primarily as a small service center for an economy based on agriculture and tourism. The social atmosphere is typical of small western towns. Local businesses have expanded gradually to accommodate service needs of vacationers who have used the area's hunting, fishing, and scenic resources increasingly over the past two decades. Demand for tourist services in Cortez has surged recently due to increasing visitor use of Mesa Verde National Park and expanding winter recreation opportunities nearby.

As in most small western towns, income levels in the area are often marginal and lifestyles are adapted accordingly. Living conditions have improved steadily by small increments as local residents have supplemented or shifted their sources of livelihood according to new economic opportunities. An increasing number of conventional houses and mobile homes in the area represent second homes for vacationing and retired persons; this increase is associated with the national trend of increased affluence and mobility of retirees.

Fiscal Status

Dolores and Montezuma counties and the Ute Mountain Ute Indian reservation form the major taxing jurisdictions in the area. Each county levies taxes for the county general fund, municipal fund, general school fund, and several special improvement districts (drainage and roads). Assessed valuation (tax base) is a measure of the property value against which county tax levies are applied; assessed valuation per capita is a measure of the size of the tax base in relation to the size of the population. This statistic (per capita assessed valuation) may reflect a community's ability to provide public facilities and services through bonded indebtedness, and thus its ability to respond to rapid growth.

The per capita valuation for Dolores County is higher than that for Montezuma County or the state of Colorado (Table 2-23). The low assessed valuation for Montezuma County may be correlated with a population growth-tax base lag, a condition characteristic of rural areas undergoing urban development; such lags are particularly prevalent in areas subject to energy exploration and development. The fact that a portion of the population is not fully represented in the tax base may also account for a portion of the county's low assessed valuation per capita; underrepresented population groups include mobile home dwellers, the Ute Mountain Ute Indians, energy exploration crews, and short-term residents.

Table 2-23. ASSESSED VALUATION OF COUNTIES AND ANTICIPATED REVENUE FOR COUNTIES, MUNICIPALITIES, SPECIAL IMPROVEMENT DISTRICTS, AND SCHOOLS IN THE CO_2 WELL FIELD AREA

County	Assessed Valuation	County Revenue	Municipal Revenue	General School Revenue	Special Improvement Districts	Total Revenue	% Increase	Total Average County Levy (per $100)	1975 Per Capita Valuation
DOLORES									
1974	$6,459,470	$135,649	$21,632	$295,696	$27,588	$480,565	17.7	$.6949	$4,660.93
1975	8,142,650	139,076	22,176	367,768	36,817	565,837			
MONTEZUMA									
1974	29,254,550	511,955	103,057	1,255,879	236,215	2,107,106	23.7	$.7847	$2,162.31
1975	33,210,980	533,036	112,832	1,501,713	458,363	2,605,944			
STATE									$3,210.11

Source: Colorado Division of Property Taxation 1976.

MAIN CO_2 PIPELINE

The proposed CO_2 pipeline would pass through 11 counties in addition to the counties in the CO_2 well field and oil field (Map 1-1). Communities within 5 miles of the pipeline corridor, their populations, and their approximate distance from the proposed pipeline route are given in Table 2-24. Because the majority of employees hired locally for pipeline construction would come from four population centers (the greater Farmington area, the Albuquerque metropolitan area, and the vicinity of Roswell and Hobbs, New Mexico), and because new-to-the-area construction workers are expected to locate in these same population centers, pertinent socioeconomic factors are presented only for these population centers. Population trends for each of the 11 counties are presented in order of position from north to south along the pipeline route in Table 2-25.

Population

Population increases are projected for each county, primarily as a result of anticipated energy development activities.

The compounded annual rate of growth exceeds 5 percent for only two counties: Lincoln and Sandoval. Sandoval's growth, which is associated with suburban encroachment from Albuquerque, is evenly distributed throughout the towns and unincorporated areas of the county. Most of Lincoln County's growth has occurred in two of its communities: Ruidoso grew by 1226 people (55 percent), from 1970 to 1975 and Capitan grew by 240 people (55 percent) during the same time period (U.S. Bureau of the Census 1977).

La Plata County experienced a population decline of 0.1 percent between 1960 and 1970; however, by 2000 it is expected to increase 60 percent from the 1970 level (projected growth is 40 percent for the state in the same period). This exceptional increase may be accounted for in part by the anticipated continuing urbanization of Durango due to its proximity to recreational opportunities and energy and water developments in the Four Corners area.

Development of San Juan coal and hydrocarbon fields in San Juan County and Grants uranium belt in McKinley County has caused energy and mineral extraction industries to grow rapidly in these two counties between 1950 and 1960. This growth is reflected in the 35 percent population increase for McKinley County and 184 percent for San Juan County. The city of Farmington accommodated 86 percent (29,700 persons out of a total 34,500) of the population influx to San Juan County during this period. Between 1960 and 1970 both counties experienced significant net out-migration (26 percent in San Juan, 20 percent in McKinley County). Compared with the 1960-1970 change in population, these figures indicate that each county may have experienced a large natural population increase for the decade.

Table 2-24. COMMUNITIES WITHIN FIVE MILES OF PROPOSED MAIN CO_2 PIPELINE

State/County	Community	Population (1970)	Approximate Distance from Pipeline (miles)
Colorado			
Montezuma	Dolores	820	1.0
	Mancos	709	0.5
La Plata	Kline	35	0.25
	Marvel	65	0.25
	Redmesa	85	2.5
New Mexico			
San Juan	Aztec	4157*	0.5
	Turley	(rural)	2.5
	Nageezi	5	0.5
Sandoval	San Luis	15	1.5
	Cabezan	(rural)	3.0
	San Ysidro	208*	2.0
	Zia	400	1.0
	Santa Ana Pueblo	400	1.0
	Angostura	250	1.0
	El Lanito	200	2.0
	Bernalillo	2454*	4.5
	Placitas	150	1.0
Santa Fe	Golden	50	3.5
	Edgewood	50	0.5
Torrance	Moriarty	1060*	1.5
	Negra	(no.pop.)	4.5
	Duran	130	1.0
Lincoln	Lon	(rural)	4.5
Chaves	High Lonesome	(rural)	2.0
Lea	Caprock	10	0.5
	Tatum	830*	2.0
	McDonald	5	4.5
Texas			
Yoakum	Allred	(rural)	3.0
	Denver City	4308*	1.5

*Population for 1975.
Source: U.S. Bureau of the Census 1977a.

Table 2-25. MAIN CO_2 PIPELINE COUNTY POPULATION CHARACTERISTICS

County	Area (Sq. Mi.)	1950 Population	1960 Population	1970 Population	% Change 1960-1970	1975 Pop. Density/ sq.mi.	Pop. July 1, 1975	% Change 1970-1975
La Plata	1,683	14,880	19,225	19,199	-.1	13.8	23,242	21.1
COLORADO	103,766	1,325,089	1,753,947	2,207,259	+25.8	24.5	2,541,311	15.1
San Juan	5,500	18,800	53,306	52,517	-1.5	11.8	64,719	23.2
McKinley	5,454	27,600	37,209	43,209	16.1	9.4	51,081	18.2
Sandoval	3,714	12,300	14,201	17,492	23.2	6.1	22,576	29.1
Bernalillo	1,169	147,700	262,199	315,774	20.4	309.7	362,087	14.7
Santa Fe	1,902	38,100	44,970	53,756	19.5	32.8	62,420	16.1
Torrance	3,346	8,000	6,497	5,290	-18.6	1.9	6,383	20.7
Guadalupe	2,998	6,800	5,610	4,969	-11.4	1.6	4,839	-.03
Lincoln	4,858	7,400	7,744	7,560	- 2.4	2.0	9,710	28.4
Chaves	6,084	40,800	57,649	43,324	-24.8	7.8	47,695	10.1
Lea	4,393	31,000	53,429	49,554	- 7.3	11.7	51,525	4.0
NEW MEXICO	121,412	684,300	951,023	1,016,000	6.9	9.4	1,143,827	12.6

Source: U.S. Bureau of the Census 1963, 1978.

Though not reflected in growth figures for San Juan County, Farmington and the nearby towns of Bloomfield and Aztec have experienced growth rates approaching annualized boom town figures. From 1970 to 1975 population increased as follows: Aztec, 25 percent; Bloomfield, 28 percent; Farmington, 27 percent. Growth at these rates continued beyond 1975 but has tapered and is soon expected to level off to rates more consistent with those of the state.

The economy in Bernalillo and Sandoval counties was primarily agrarian until the advent of energy and mineral explorations in the Four Corners area during the 1950s. Military installations and nuclear research have also been large employers in the area since the 1940s. The population in these two counties more than doubled between 1950 and 1970; nearly all of the growth occurred in Albuquerque, the principal city and county seat of Bernalillo County. Today, the two counties constitute the largest Standard Metropolitan Statistical Area in New Mexico.

The U.S. Bureau of the Census (1970) recorded 77 percent of the total population in Bernalillo County as residing in the city of Albuquerque. In contrast, only 12 percent of the total 1970 population resided in Bernalillo, the principal city in Sandoval County.

Santa Fe and Torrance counties have had dissimilar historical growth patterns. Between 1960 and 1970 the percent change was 20 percent for Santa Fe County and -19 percent for Torrance County (Table 2-25). Santa Fe, the principal city in Santa Fe County, had 77 percent of the county's total population in 1970. Torrance County is rural by U.S. Census Bureau definition; none of its cities had more than 2500 persons in 1970. The county seat, Estancia, had 13.6 percent of the county's total 1970 population.

Guadalupe and Lincoln counties, which are characteristically rural, have undiversified economies and no urban population centers. Both counties registered a population loss for the period between 1960 and 1970. Changes during that time period were -11 percent in Guadalupe County and -2 percent in Lincoln County: Lincoln County has experienced a recent (1970-1975) population growth however, probably associated with increased tourism centering around the Lincoln National Forest in Lincoln County and the neighboring Mescallero Apache Indian Reservation in Otero County.

Historically, the economy of Chaves and Lea counties in southeastern New Mexico was primarily supported by agriculture; however, in the 1940s and 1950s development of mineral and hydrocarbon industries and establishment of Walker Air Force Base broadened the area's economic base. Both counties experienced large population increases between 1950 and 1960, which may be associated with intense oil and gas development in the region. Urban development in Lea County during that

decade centered around Hobbs, its principal city, located approximately 20 miles southeast of Lovington. The majority of growth in Chaves County took place in the vicinity of Roswell, an established agricultural trading town and the county's principal city.

From 1960 to 1970, both counties registered a decrease in population. Percent population decreases in this period were 25 and 7 percent for Chaves and Lea counties, respectively. The substantial out-migration from Chaves County may be attributed to the closing of Walker Air Force Base in 1967 as well as the transfer of major regional oil industry facilities from Roswell to Midland, Texas. The population loss between 1960 and 1970 in Lea County was due to the decline of the mineral industry in the area.

In summary, the New Mexico counties experiencing high growth rates are characterized by energy resources production (San Juan and McKinley counties); urban expansion (Sandoval and Torrance counties); and resort development and tourism (Lincoln County). Many of the counties crossed by the proposed project have experienced ups and downs in the past and are currently undergoing rapid change. Population characteristics of Gaines and Yoakum counties in Texas will be unaffected by the pipeline project.

Economy

Unemployment rates from 1970 to 1975 decreased in several counties as a result of increased energy, minerals, and hydrocarbon production. In 1975, the average state unemployment rate was 6.9 percent in Colorado and 10.0 percent in New Mexico. Of the 11 counties in the proposed pipeline area, only San Juan, Santa Fe, Torrance, and Guadalupe showed unemployment rates in excess of state averages. Employment in contract construction as a percentage of total employment increased in most of the 11 counties from 1970 to 1975 (Table 2-26).

Additional economic indicators other than employment include the percent of the population to receive welfare payments, the percent eligible for food stamps, and average weekly earnings (Table 2-27). Though a large percentage of McKinley County's population receives welfare payments, wages in private industry are among the highest in the state. This apparent contradiction may be due to mining and construction companies operating in the area that offer employment at higher-than-average wages. In addition part of the Navajo Reservation, long plagued by high levels of unemployment, is located in McKinley County. Private industry workers also receive comparatively high weekly earnings in Lea and McKinley counties, which are also involved in mining and/or natural resource production. Because large percentages of populations in Bernalillo and Santa Fe are employed by state or federal government agencies rather than by private industry, weekly earnings in these counties may be misleadingly low.

Table 2-26. EMPLOYMENT BY INDUSTRY BY COUNTY IN PIPELINE AND OIL FIELD AREAS

	La Plata, Colorado				San Juan, New Mexico			
	1970	1972	1974	1976	1970	1972	1974	1976
Total*	3601	4318	5263	5862	10,148	10,766	13,462	15,313
Contract construction	162	171	375	555	1285	932	1083	1326
Agricultural services, forestry, fisheries	10	7	0-19	14	D**	5	0-19	0-19
Mining	148	171	100-249	100-249	1617	1889	3077	3163
Manufacturing	240	509	665	398	1704	1218	766	697
Transportation and other public services	291	321	269	350	981	977	1168	1457
Wholesale trade	174	143	212	100-249	613	669	979	943
Retail trade	1185	1277	1527	1776	2227	2566	3029	3715
Finance, insurance, and real estate	168	194	260	308	334	392	435	598
Services	1199	1510	1678	2083	1305	2022	2771	3339

*Numbers for subsequent categories are from different sources and therefore do not sum exactly to total.
**D = figures withheld to avoid disclosing figures for individual companies.

Source: U.S. Bureau of the Census 1971a, c, d; 1973b, c, d; 1975a, b, c; 1977b, c, d.

Table 2-26. (continued)

	McKinley, New Mexico				Sandoval, New Mexico			
	1970	1972	1974	1976	1970	1972	1974	1976
Total	6427	7462	7944	10,261	1141	1642	2153	1984
Contract construction	201	554	247	861	406	235	239	237
Agricultural services, forestry, fisheries	D	D	0-19	0-19	D	27	20-99	10
Mining	927	663	239	977	D	D	204	131
Manufacturing	1155	1204	1380	1261	142	249	480	337
Transportation and other public services	547	604	271	520	13	21	40	151
Wholesale trade	379	419	355	733	20	28	20-99	77
Retail trade	1829	2329	3158	3347	187	287	357	362
Finance, insurance, and real estate	282	291	312	329	73	119	70	88
Services	1070	1332	1641	2234	277	503	559	570

Table 2-26. (continued)

	Santa Fe, New Mexico				Bernalillo, New Mexico			
	1970	1972	1974	1976	1970	1972	1974	1976
Total	10,166	12,034	14,015	15,144	79,195	94,482	105,690	111,880
Contract construction	856	1218	1558	1447	7789	11,893	11,796	10,595
Agricultural services, forestry, fisheries	30	28	38	52	227	364	323	407
Mining	D	231	61	77	262	174	259	483
Manufacturing	701	686	964	1004	9073	10,685	14,362	14,592
Transportation and other public services	530	689	646	887	5932	7375	7436	7522
Wholesale trade	399	421	500	532	6278	7368	7911	8903
Retail trade	2952	3665	4643	4950	18,700	21,509	25,111	28,776
Finance, insurance, and real estate	737	797	854	1130	5649	7378	7378	7933
Services	3448	4112	4447	5002	24,869	26,912	29,824	32,225

Table 2-26. (continued)

	Torrance, New Mexico				Lincoln, New Mexico			
	1970	1972	1974	1976	1970	1972	1974	1976
Total	340	341	448	531	981	1453	1400	1567
Contract construction	D	8	16	24	84	537	189	170
Agricultural services, forestry, fisheries	0	D	0-19	0-19	D	16	0-19	0-19
Mining	0	0	0	0	D	D	20-99	0-19
Manufacturing	D	D	0-19	20-99	37	43	46	61
Transportation and other public services	20	21	60	57	87	100	49	101
Wholesale trade	19	D	12	25	30	31	47	99
Retail trade	238	252	258	339	396	415	429	502
Finance, insurance, and real estate	10	14	26	27	75	72	177	195
Services	45	28	27	24	254	194	347	411

Table 2-26. (continued)

	Chaves, New Mexico				Lea, New Mexico			
	1970	1972	1974	1976	1970	1972	1974	1976
Total	8994	9431	9596	10,673	12,702	13,088	14,437	16,416
Contract construction	780	683	809	874	735	999	1200	1230
Agricultural services, forestry, fisheries	102	131	102	97	20	31	20-99	44
Mining	471	457	164	230	3826	3740	5265	5455
Manufacturing	1602	1630	1840	2024	594	677	950	1000
Transportation and other public services	722	790	909	904	1780	1770	915	1349
Wholesale trade	654	698	834	872	841	700	943	1111
Retail trade	2247	2342	2618	3112	2758	2954	2719	3202
Finance, insurance, and real estate	695	786	585	724	442	533	653	711
Services	1637	1814	1650	1791	1668	1645	1673	2291

Table 2-26. (concluded)

	Yoakum, Texas				Gaines, Texas			
	1970	1972	1974	1976	1970	1972	1974	1976
Total	1855	1711	2738	3838	2026	1724	1791	2072
Contract construction	66	65	77	20-99	39	42	68	125
Agricultural services, forestry, fisheries	0	0	0	6	0	9	12	60
Mining	859	738	1745	2881	851	616	584	682
Manufacturing	65	74	91	20-99	202	163	142	226
Transportation and other public services	228	210	108	130	108	117	82	122
Wholesale trade	72	100	147	133	75	58	202	196
Retail trade	318	327	320	284	491	512	427	403
Finance, insurance, and real estate	53	D	47	20-99	63	58	88	75
Services	179	155	196	208	183	120	173	182

Table 2-27. INDICATORS OF ECONOMIC CONDITIONS (1976)

	Population					
	Mid-1976[a]	% Change April 1970 (Census) Mid-1976	% of Labor Force Unemployed[b]	% of Population Receiving Welfare Payments[b]	% of Population Certified Eligible For Food Stamps[b]	Average Weekly Earnings[c]
NEW MEXICO	1,168,000	14.9	9.1	5.0	13.0	$172
Bernalillo	364,800	15.5	9.8[d]	4.9	11.1	176
Chaves	49,000	13.0	7.5	4.8	10.1	151
Guadalupe	4,900	-1.3	10.1	8.4	25.9	105
Lea	54,400	9.8	4.3	3.5	7.2	204
Lincoln	10,100	33.2	5.4	3.4	11.3	126
McKinley	56,000	29.5	7.6	7.4	18.3	197
Sandoval	23,400	33.7	–[d]	6.7	19.6	142
San Juan	67,700	29.0	10.2	5.4	13.1	208
Santa Fe	63,800	16.5	9.6	4.8	14.0	145
Torrance	6,900	30.2	13.0	5.8	23.7	114

Sources: U.S. Bureau of the Census 1976; Employment Security Commission of New Mexico 1976.

[a]Provisional.

[b]1976 monthly average.

[c]1976 quarterly average.

[d]Combined for Bernalillo and Sandoval counties.

Primary and Secondary Services

The demand for housing has generally increased in the 11 counties, with a short or marginal supply in the Four Corners area and around large urban centers (Table 2-28). Counties which are economically agricultural or oil-based in eastern New Mexico generally show near-static conditions or housing surpluses. While there may be some shortage of permanent housing, the cities of Albuquerque, Hobbs, Farmington, and Roswell have substantial temporary housing facilities and are expected to attract the majority of pipeline construction employees in need of housing. Each of these towns has large numbers of motel and hotel units to supplement temporary housing demands, although displacement of tourists from these facilities is not expected.

Current vacancy rates for rental housing are not available for the four population centers in which pipeline construction employees are expected to seek temporary housing. Communications with both the Chamber of Commerce and representatives of the Board of Realty in these centers indicated that this statistic is not systematically collected. In the cases of the Farmington vicinity, Albuquerque, Roswell, and Hobbs, rental housing is available but vacancy rates are generally low: 3 to 4 percent at most. Mobile home rentals are common in each of these areas.

Fiscal Status

Property tax, the principal device for taxing a pipeline project, is usually based on a fraction of the constructed value of the project in each taxing jurisdiction. The principal agent for property assessment in Colorado and New Mexico is the county government; school districts and special districts may levy taxes in addition to those of the county, but as a rule these levies are based on the county assessment. Assessment ratios and conventions vary between and within states. Tax rates (applied to assessed valuations) are also variable, although their structure and limits may be set by state law. Per capita assessed valuation measures the strength of the tax base relative to the population that tax revenues must serve. Within an individual state, county assessed valuation per capita is a measure of relative fiscal vitality (capability to fund and maintain public improvements over the long run).

The higher per capita valuations within New Mexico occur in San Juan, Lincoln, and Lea counties (Table 2-29) where hydrocarbon and mineral extraction activities are prevalent. The per capita valuation of McKinley County (the lowest of the counties compared) is subject to rapid upward revision in the near future due to a rapidly developing uranium mining and milling industry, as well as 1977 changes in the tax structure for that industry.

In addition to county property taxes, each of the states levies oil and gas severance taxes. These taxes constitute a sizable portion

Table 2-28. MAIN CO_2 PIPELINE COUNTY HOUSING CHARACTERISTICS

	Total Housing Units		% Change	Total Occupied Units		Total Owner Occupied Units (%)		Total Renter Occupied Units (%)		Vacancy Rates: Owner Occupied		Vacancy Rates: Renter Occupied	
	1960	1970	1960-1970	1960	1970	1960	1970	1960	1970	1960	1970	1960	1970
COLORADO													
La Plata	6,815	6,398	-6.1	5,490	5,683	70.0	70.8	30.0	29.2	5.7	1.1	18.9	10.0
NEW MEXICO													
San Juan	14,280	14,960	+4.8	12,999	13,269	72.6	67.9	27.4	32.1	8.9	1.3	31.4	10.5
McKinley	8,199	10,586	+29.1	7,701	9,675	68.1	55.8	31.9	44.2	9.2	.7	13.5	3.7
Sandoval	3,354	4,785	+42.7	2,964	4,141	73.8	80.2	26.2	19.8	4.6	.6	12.8	6.6
Bernalillo	76,809	98,634	+28.4	71,578	94,223	68.3	65.3	31.7	34.7	16.1	1.3	46.5	5.6
Santa Fe	12,384	16,135	+30.3	11,695	15,300	65.4	67.5	34.6	32.5	7.4	1.2	30.5	4.8
Torrance	2,098	1,919	-8.5	1,735	1,621	73.7	75.9	26.3	24.1	7.2	5.3	17.6	17.5
Guadalupe	1,617	1,649	+2.0	1,410	1,346	71.4	71.2	28.6	28.8	6.3	1.6	20.8	10.6
Lincoln	4,091	4,950	+21.0	2,291	2,440	65.5	73.6	34.5	26.4	3.0	6.6	6.8	24.9
Chaves	17,119	17,786	+3.9	15,680	13,174	57.6	66.9	42.4	33.1	10.7	17.5	38.4	26.7
Lea	17,131	17,158	+.2	15,075	14,075	61.9	69.6	38.1	30.4	11.6	3.6	48.8	17.9

Source: U.S. Bureau of the Census 1963, 1973a.

Table 2-29. VALUATIONS, REVENUES, AND TAX RATES FOR MAIN CO_2 PIPELINE AND OIL FIELD COUNTIES

	Valuation		Percent	County Revenue		Total Revenue	
	1974	1975	Change	1974	1975	1974	1975
COLORADO[a]							
La Plata	59,787,320	67,323,920	12.6	1,180,000	1,471,547	4,576,787	5,300,658
NEW MEXICO[b]							
San Juan	294,361,312	339,596,891	15.3	2,129,845	2,002,269	3,496,210	3,431,685
McKinley	78,447,761	87,824,654	11.9	1,048,636	1,064,981	1,769,936	1,312,851
Sandoval	71,614,378	78,264,395	9.2	750,167	820,009	1,644,994	1,452,936
Bernalillo	790,769,443	870,471,462	10.0	17,359,007	19,519,468	28,333,028	30,745,967
Santa Fe	117,141,725	123,991,793	5.8	1,856,009	1,770,940	2,871,199	7,022,400
Torrance	23,842,634	24,120,924	1.1	354,656	368,266	618,100	555,024
Guadalupe	14,643,152	14,925,360	1.9	281,294	403,164	450,287	527,423
Lincoln	47,602,038	51,892,731	9.0	775,282	707,711	1,265,699	1,060,999
Chaves	100,446,682	106,190,596	5.7	3,626,019	3,454,984	4,955,132	4,168,339
Lea	360,124,708	473,400,456	31.4	4,319,922	2,478,865	4,942,423	3,406,715
TEXAS							
Yoakum[c]	211,628,840	235,182,200	11.1	--	--	--	--
Gaines[d]	173,133,470	210,390,210	21.1	--	--	--	--

Sources: [a]Transrep Bibliographics 1977.
[b]New Mexico State Department of Finance and Administration 1975.
[c]Yoakum County Tax Assessor 1977.
[d]Gaines County Tax Assessor 1977.

of the state revenues in New Mexico and Texas in particular; however, it has not been determined whether these taxes apply to CO_2 gas.

OIL FIELD

The Wasson Oil Field in West Texas straddles Yoakum and Gaines counties. Denver City, the population center closest to the oil field, is the principal town of Yoakum County and is a small oil and farming center for both Yoakum and Gaines counties. Most of Denver City's approximately 4000 residents are directly or indirectly involved in oil extraction (see Table 2-26). Lubbock, 80 miles from the Wasson Oil Field, is a major city (with population greater than 140,000 in 1970) and serves as a trading center for Denver City. Lubbock, as well as Hobbs, has complete primary public services, complete secondary consumer services, and a large labor pool with many persons skilled in oil extraction activities.

Yoakum and Gaines counties have lower assessment rates and higher per capita valuations than the counties in Colorado and New Mexico. These characteristics may be associated with the extensive oil and gas extraction activities that dominate the area's economy. In addition to county property taxes, the state of Texas also levies oil and gas severance taxes. These taxes constitute a sizable portion of the state's revenue; however, it is not known if such taxes are applicable to CO_2.

FUTURE ENVIRONMENT

INTRODUCTION

Increasing demand for domestic energy supplies is expected to continue over the next three decades. Energy-producing industries will continue to pressure for development of coal and uranium deposits in Colorado and New Mexico, particularly those in the Four Corners area. Against this background, the following discussion considers the probable future environment of the CO_2 well field, pipeline, and oil field areas in the absence of the proposed project. The time period considered encompasses the proposed 30-year economic life of the project (1982 through 2012). Only those areas expected to change are discussed here. Resources not mentioned are expected not to change significantly.

AIR QUALITY

MAIN CO_2 PIPELINE

No change in future air quality is expected along the proposed route except in the vicinity of the proposed Star Lake-Bisti coal mining region where an increase in particulates, sulfur dioxide, nitrogen oxides, and hydrocarbons will occur if mining commences.

WATER RESOURCES

CO_2 WELL FIELD

Surface flow availability from the Dolores River, which passes through the Doe Canyon Field, will be lowered in the future due to anticipated increases in the rate of local water consumption and water supplied to the Dolores River Project. Dolores River water consumption is expected to increase as the local population grows. Similarly, the Dolores Project will reduce existing flows by diverting 105,200 acre-feet of Dolores River water for irrigation purposes from a point just past the town of Dolores to the San Juan River Basin. Such a diversion would reduce the surface flows passing through the Doe Canyon Field, especially during periods of high flow (e.g., snowmelt period in late spring).

MAIN CO_2 PIPELINE

Surface flows observed in major water courses (e.g., San Juan, Rio Grande, and Pecos rivers) are expected to decline due to continued growth in area-wide water consumption as the population growth in this 13-county area continues.

VEGETATION

CO_2 WELL FIELD

Vegetation is expected to continue to be affected during the next 30 years. Livestock grazing will continue to be a major factor determining the composition and abundance of plant species in the area. The extent of "chaining" or use of similar methods is expected to be minor in the CO_2 well field compared with the amount of area "chained" during the past 10 to 20 years.

Conversion of natural vegetation types to agricultural crops has historically caused the most drastic change to vegetation in the project area. Though this trend may continue, it is expected to decrease since arable lands are less available than in the past.

MAIN CO_2 PIPELINE

Vegetation resources along the pipeline route will continue to be affected by livestock grazing and agricultural expansion but are not expected to undergo major changes. The most probable expansion of agricultural lands will occur near the pipeline route in southeastern New Mexico and West Texas.

OIL FIELD

Vegetation resources in the oil field near Denver City, Texas will continue to be disturbed by ongoing oil facilities until conventional oil recovery methods are terminated. When the oil field is no longer occupied, the grassland vegetation will regenerate in some of the disturbed areas.

FISH AND WILDLIFE

CO_2 WELL FIELD

Wildlife populations will continue to undergo gradual changes in abundance and distribution, primarily due to increased human activities associated with population growth. Wildlife populations in the proposed CO_2 well field vicinity will be similar in general to those currently in the area; however, wildlife changes may be severe in those areas where vegetation undergoes major alteration.

Demand for big game species will gradually increase as the population (and associated hunters) increase in the region.

Most smaller wildlife species (rabbits, rodents, and many small birds) are expected to undergo little change in population structure or distribution near the CO_2 well field. Birds of prey may slowly decline in number during the next 30 years as these species generally need seclusion, especially during breeding and nesting periods. Waterfowl numbers may increase somewhat in the CO_2 well field region as a result of the Dolores Project.

Fish populations in the streams near the CO_2 well field are expected to remain fairly constant except where affected by new dams or irrigation projects. Alteration of stream habitat and creation of reservoirs as a result of the Dolores Project may alter the species composition of fish in the Dolores River.

MAIN CO_2 PIPELINE

Gradual changes in wildlife population sizes and distributions are expected in areas altered by agricultural expansion, especially in southeastern New Mexico and West Texas. Most species, such as small mammals and birds, should remain relatively stable as much of the habitat along the proposed pipeline route is expected to remain relatively unchanged.

OIL FIELD

Wildlife populations are expected to increase gradually in the area if oil field operations decline. Population increases would be most noticeable for species that were more common in the area prior to development of the oil field (e.g., deer and antelope).

CULTURAL RESOURCES

WELL FIELD

The Dolores Project will increase availability of archaeological information, thereby increasing the data base for scientific evaluation of the prehistoric Southwest. At the same time, however, incidence of theft to excavation sites will increase with increased availability of excavated items and increased numbers of visitors. The Dolores Project, if implemented, will inundate an unknown number of archaeological sites.

VISUAL RESOURCES

MAIN CO_2 PIPELINE

The visual resources of the pipeline area are likely to be affected by construction of energy resource development facilities over the next 30 years. Modifications such as rights-of-way, developed highway systems, mining and industrial facilities, and communications networks can be expected to become characteristic of the landscape. In addition, undeveloped areas at the outskirts of urban areas, such as Albuquerque and Farmington, can expect encroachment from the cities since energy-related urban growth is expected to accompany local resource development. Conversion of agricultural and undeveloped lands is expected to be insignificant, with minimal effect on visual resources.

WILDERNESS VALUES

CO_2 WELL FIELD

The primary determinant of future wilderness values in this area is due before June 1980. It is presently unknown whether or not Congress will designate areas in the vicinty of the proposed CO_2 well field as part of the BLM wilderness inventory. Wilderness inventory designation would require retaining the area at its current level of low-intensity use.

Multiple-use activities in predesignated wilderness study areas would continue with advance planning to protect wilderness values and roadless characteristics.

MAIN CO_2 PIPELINE

Multiple-use activities in predesignated wilderness study areas would continue with advance planning to protect wilderness values and roadless characteristics.

RECREATIONAL RESOURCES

CO_2 WELL FIELD

Demand for future recreational use within the CO_2 well field would increase moderately. Sightseeing of the region's vast archaeological resources is expected to increase as public awareness and tourism grow, and as preservation and restoration continue to take place. Development of the Dolores Project and possible inclusion of the Dolores River into the Wild and Scenic Rivers system would attract more recreation visitors and provide further recreational opportunities.

MAIN CO_2 PIPELINE

Recreation use along the pipeline route is expected to increase slightly. No major change in recreational activities along the route is expected; however, development would displace some activities and result in an overall reduction of opportunity for solitude, primitive values, and sightseeing. Increased use by hunters, off-road vehicle users, and sightseers is anticipated in conjunction with local population increases. These recreational uses will be restricted where land is privately owned.

AGRICULTURAL RESOURCES

CO_2 WELL FIELD

Livestock grazing will continue as the major land use in the vicinity of the CO_2 well field. More intensive management and an increase in range improvement on all planning units will increase forage production and improve wildlife habitat. Development of the Dolores Project will alter farm production considerably; approximately 4000 acres of dry farmland and approximately 450 acres of grazing land within the CO_2 well field will be converted to irrigated farmland.

TRANSPORTATION NETWORKS

CO_2 WELL FIELD

Local transportation improvements will continue as required. Existing roads within the CO_2 well field will experience limited increased use due to increased recreational travel.

MAIN CO_2 PIPELINE

Highways crossed by the pipeline route are not expected to undergo large-scale improvements and construction of new highways is not anticipated. The expected increase in population and automobile travel will require accelerated maintenance of existing roads.

OIL FIELD

Local maintenance and upkeep of existing roads are expected.

SOCIOECONOMICS

CO_2 WELL FIELD

Social and economic conditions are expected to change gradually to accomodate the small but steady influx of second home builders and year-round tourists. By the end of the proposed CO_2 project life, (2012), Dolores and Montezuma counties are likely to be socioeconomically similar to what each would be without the project. By that time, Cortez will

have expanded to provide for increasing demands for seasonal recreation and other tourist-related services.

MAIN CO_2 PIPELINE

The Aztec-Bloomfield-Farmington area and Albuquerque are likely to continue to grow in response to energy-related development but at a slower pace than in the recent past. By 2012, the growth in the general Farmington area is likely to have leveled off as new projects will be well into operational phases. Continued but slow growth in Albuquerque and the Roswell/Hobbs area is expected to be associated with the general national trend in migration to the Sunbelt region.

OIL FIELD

An estimated 50 to 60 current oil field employees would be transferred gradually from the area over the next 20 years due to depletion of oil reserves recoverable by waterflooding. This small and gradual out-migration would not affect ongoing social processes in the area, though a slowdown in oil field production may be followed by some out-migration of associated equipment industries to other more active production fields. This potential out-migration is likely to be economically balanced by small area growth through Sunbelt in-migration. Thus, until the year 2012, the area should experience only slight changes in social or economic characteristics.

CHAPTER 3

ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION

This chapter identifies and analyzes impacts of the proposed project. Each impact is identified in a cause and effect relationship, including those secondary impacts having significance. All impacts are traced to the point of insignificance.

The cause of an impact is tied to a component of the proposed action as identified in Chapter 1. The effect of the impact is tied to a component of the environment described in Chapter 2. The impacts discussed in this chapter were assessed on the basis of the description of the proposed action presented in Chapter 1. This assessment took into account the project design features and federally required measures to minimize environmental impacts. The absence of discussion of impacts indicates the analyses either determined that an impact would not occur, or that it would be insignificant.

ASSUMPTION AND ASSESSMENT GUIDELINES

1. Most of the proposed project would be constructed between 1980 and 1982. Rehabilitation measures would be initiated immediately upon the completion of discrete phases of the construction operations. Some measures would be delayed to the most opportune time to insure the maximum probability of success (i.e., seeding would be done in the fall of the year).

2. The project would have an expected 30 year life. After the 30 year period many of the components would be salvaged, and the land on which they had lain would be rehabilitated. However, considering the size of this project, it is assumed that some facilities would be used in place for other projects. Therefore, an unknown proportion of the constructed facilities would be permanent structures.

3. Some or all of the vegetation would be removed on approximately 6551 acres during construction (Table 3-1).

4. Approximately 397 acres would be occupied by buildings or otherwise excluded from revegetation processes for the 30 year life of the proposed project.

Table 3-1. SUMMARY OF PROJECT LAND REQUIREMENTS

	Acres Required			
	Construction[a]			Operation
	Years to Construct	Total Disturbed	Revegetated	Committed[b]
CO_2 Well Field				
• New access roads[c]	1980 to 1985	0	0	70
• Well facilities	1980 to 1985	266	196	70
• Wet-CO_2 gathering lines	1980 to 1985	1152	1082	0
• Central facilities	1981 to 1982	65	0	65
• Dry-CO_2 gathering lines	1980 to 1982	756	756	0
• Electric transmission line system[d]	1981	37	23	14
TOTAL -	1980 to 1985	2276	2057	219
Main CO_2 Pipeline System				
• Origin station	1981	4	0	4
• Right-of-way	1980 to 1981	2899	2899	0
• Compressor station	1981	8	0	8
• Major river crossings	1980 to 1981	4	4	0
• Communications network	1981	63	54	9
• Electric transmission line system[d]	1980 to 1981	2	0	2
TOTAL -	1980 to 1981	2980	2957	23
Denver Unit				
• New well facilities	1980 to 2000	190	140	50
• New well flow lines	1980 to 2000	150	150	0
• Expansion of satellite stations	1982 to 1984	50	0	50
• New gas-gathering pipelines	1982 to 1984	250	250	0
• New gas-gathering compressors[e]	1981 to 1988	25	0	25
• New gas-treating plant and compressors	1981 to 1985	30	0	30
• New CO_2-injecting pipelines	1980 to 2000	600	600	0
TOTAL -	1980 to 2000	1295	1140	155
PROJECT TOTAL -	1980 to 2000	6551	6154	397

[a] Includes time to initiate rehabilitation measures, but not length of time to establish a stand of native vegetation.
[b] Estimate of amount of land that would be committed for the life of the project.
[c] Included in wet-CO_2 gathering line estimate.
[d] Right-of-way clearing not required.
[e] If required.

5. Work force requirements for the proposed project would peak at an estimated 2255 persons during construction in 1981 (Table 3-2). The total work force requirements after 1983 would be less than 200 people for most years until project termination in about 2012.

6. The project would be implemented as described in Chapter 1, without significant changes that would alter the scope or timing of the proposal.

7. The existing environment would remain essentially as described in Chapter 2 during implementation and operation of the proposed action.

AIR QUALITY

CO_2 WELL FIELD

Construction

Particulate matter and gaseous pollutants would be emitted into the atmosphere during construction of well facilities, central facilities, gathering lines, and access roads in the CO_2 well field. Fugitive dust would be generated by earth-moving and construction equipment, by pipeline digging operations, and by wind erosion from exposed soil. Gaseous and particulate emissions would come from exhaust pipes of vehicles and machines in the construction fleet.

Gaseous and particulate emissions have been estimated from projected construction data as described in Appendices A-1 and A-2. The total emissions that might occur during a year of intensive construction are given in Table 3-3.

Background particulate concentrations may climb as high as 120 $\mu g/m^3$ due to the common occurrence of strong blowing winds (see Chapter 2, Air Quality). Under the dry soil conditions common to the region, natural wind erosion rates are large. During periods of strong winds, construction activities would contribute to the high background concentrations, and intermittent violations of the air quality standards would occur.

Air quality in the CO_2 well field would be temporarily degraded during the construction phase by gaseous emissions from the construction fleet. Although little data are available, background concentrations of gaseous pollutants are estimated to be low. Gaseous emissions would be temporary, intermittent, and localized. The effect on regional air quality would be small, and regulatory standards should not be violated.

Table 3-2. WORK FORCE REQUIREMENTS

Project Component	Year								
	1980	1981	1982	1983	1984	1985	1986	1987	1988
WELL FIELD									
Construction (Total)	305	350	470	345	60	60	10	10	10
Well sites and access roads	120	120	90	70	35	35	5	5	5
Central facilities	0	90	140	90					
Wet-CO_2 gathering lines	40	80	140	85	25	25	5	5	5
Dry-CO_2 gathering lines	70	60	100	0					
Electric facilities	75								
Operation (Total)	20	40	40	40	40	40	40	40	40
CO_2 MAIN PIPELINE									
Construction (Total)	1255	1355							
Origin station	6								
Pipeline	1250	1250							
Compressor station		64							
Communications network		6							
Operating and maintenance bases		6							
Electric facilities		30							
Operation (Total)			24	24	24	24	24	24	24
OIL FIELD									
Construction (Total)									
Well-sites		480	260		20	200	20	20	
Gathering lines, pipe-		40	40						
lines		100	100						
Gas treatment plant		200				200			
Compressor stations		120	120		20		20	20	
Electric facilities		20							
Operation (Total)			120	120	120	120	120	120	120
TOTAL PROJECT WORK FORCE	1580	2225	914	429	264	444	214	214	184

Table 3-3. ESTIMATED ANNUAL CONSTRUCTION AND OPERATION EMISSIONS

	CO_2 Well Field (tons/yr)		Main CO_2 Pipeline (tons/yr)		Oil Field (tons/yr)	
	Construction	Operation	Construction	Operation	Construction	Operation
Particulates	530	5	438	Negligible	335	-
Carbon Monoxide (CO)	696	4	860	Negligible	773	1630
Nitrogen Oxides (NO_x)	148	27	264	Negligible	146	4070
Sulfur Dioxide (SO_2)	10	57	19	Negligible	10	2
Reactive Hydrocarbons (RHC)	32	1	43	Negligible	34	510

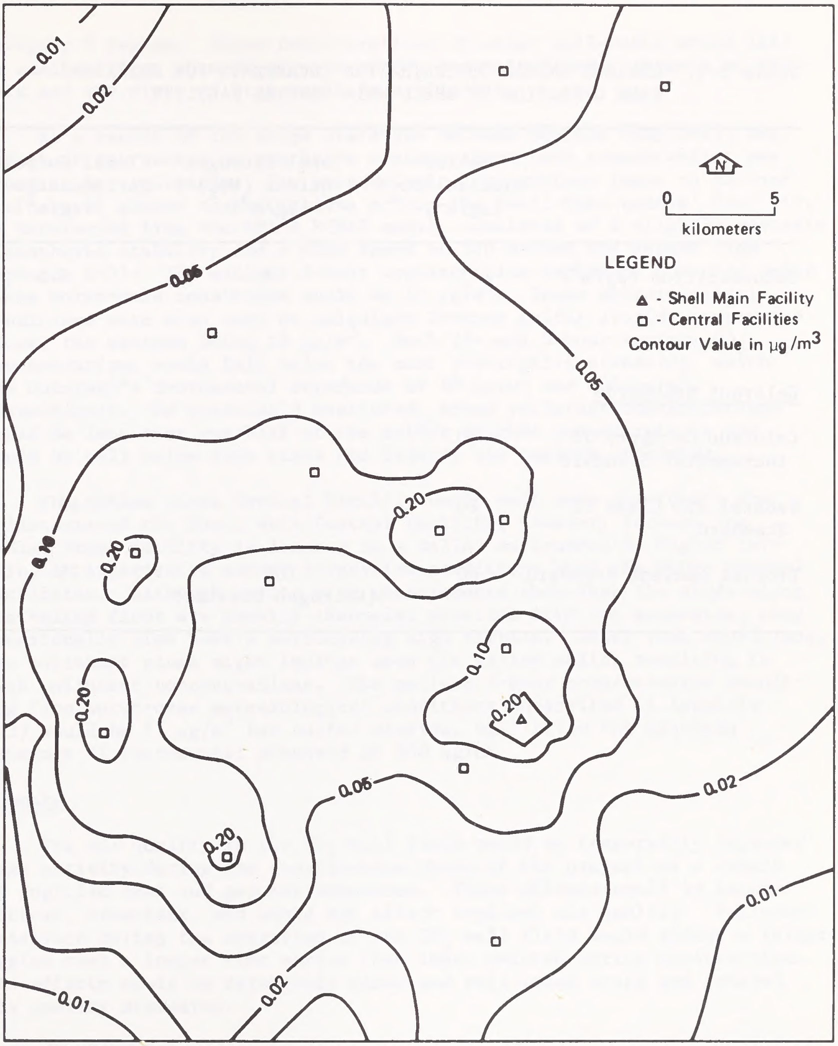
Operation

During the operation of the CO_2 well field, pollutants would be continuously emitted into the atmosphere by fuel-fired glycol heaters at the central facilities and by fuel-fired line heaters at the Mobil wells. Emissions from these sources, calculated with fuel consumption data and U.S. Environmental Protection Agency (EPA) emission factors as described in Appendix A-2, are given in Table 3-3. In general, the major sources for these data were located atop plateaus where dispersion conditions were good.

Annual concentration increments resulting from these sources were simulated using a modified version of the EPA Valley model, described in Appendix A-3. Modeling results show that the source with the greatest emissions, the Shell Main Central Facility, would produce the largest ground-level pollutant concentrations. Emissions from each source were found to have little effect on concentrations at another source, primarily due to the large distances that separated major sources. For example, emissions from the Shell Main Central Facility alone would produce a maximum annual sulfur dioxide (SO_2) concentration increment of 4.59 $\mu g/m^3$ (located 70 meters north-northeast of the facility), while the concentration increment at the same location resulting from all other sources would be only 0.04 $\mu g/m^3$. These concentrations drop off rapidly with distance; the maximum annual SO_2 concentration at a distance of 1 kilometer from the main facility is predicted to be 0.34 $\mu g/m^3$.

The concentration increments for SO_2 over the entire well field (Map 3-1) would be well below the Colorado annual incremental SO_2 standard of 10 $\mu g/m^3$ for Category II regions, which is the most restrictive standard applicable to the CO_2 well field. Nitrogen oxide (NO_x), total suspended particulates (TSP), carbon monoxide (CO), and hydrocarbon (HC) concentrations would be expected to be 50 percent, 10 percent, 8 percent, and 1 percent, respectively, of the SO_2 concentrations. Annual concentration increments for the Shell Main Central Facility are 5, 2, and 0.5 $\mu g/m^3$ for SO_2, NO_x, and TSP, respectively (Table 3-4). Actual concentrations would be the sum of the concentration increment and the background concentration. Since background concentrations in the area are generally low, pollutant concentrations would remain well below ambient air quality standards (Table 3-4).

Annual concentrations at the nearest state boundary (Utah, 30 km west of the Shell Main Central Facility) and the nearest prevention of significant deterioration (PSD) Category I area (Mesa Verde National Park, 25 km southeast of the Shell Main Central Facility) were estimated as described in Appendix A. Concentration increments at the Utah border would be about 0.03 $\mu g/m^3$; concentration increments at the National Park boundary would be about 0.005 $\mu g/m^3$. The latter is well below the Colorado annual SO_2 incremental standard of 2 $\mu g/m^3$ applicable to a



Map 3-1. ANNUAL CONCENTRATION INCREMENTS OF SULFUR DIOXIDE IN CO_2 WELL FIELD REGION

Table 3-4. MAXIMUM ANNUAL CONCENTRATION INCREMENTS FOR EMISSIONS FROM OPERATION OF SHELL MAIN CENTRAL FACILITY

	Sulfur Dioxide (SO_2) ($\mu g/m^3$)	Total Nitrogen Oxides (NO_x) ($\mu g/m^3$)	Total Suspended Particulates (TSP) ($\mu g/m^3$)
Concentration ($\mu g/m^3$)	5	2	0.5
Relevant Standards			
Colorado Category II Incremental Standard	10	-	-
Federal PSD Class II Standard	20	-	19
Federal Ambient Standard	80	100 (Nitrogen Dioxide)	75

Category I region. Since concentrations of other pollutants would also be smaller (less than 50 percent of SO_2 concentrations), impacts on the park and the state of Utah would be negligible.

As a result of the large distances between sources (Map 3-1), the effect of one source on another's maximum short-term concentration was found to be negligible. The meteorological conditions found to produce the largest ground concentrations around the Shell Main Central Facility, as determined from the EPA's PTMAX model, consisted of a slightly unstable atmospheric stability and a wind speed of 3.0 meters per second (see Appendix A-3). The maximum 3-hour concentration increment computed under these worst-case conditions would be 12 $\mu g/m^3$. These meteorological conditions were also used to calculate 24-hour sulfur dioxide concentrations, the maximum being 19 $\mu g/m^3$. Both 24- and 3-hour maximum SO_2 concentrations would fall below the most restrictive standards, which are Colorado's incremental standards of 50 $\mu g/m^3$ and 300 $\mu g/m^3$, respectively. As previously mentioned, other pollutant concentrations would be less than one-half of the sulfur dioxide concentrations and would be well below both state and federal air quality standards.

The McElmo Creek Central Facility would emit only one-fourth the pollutants of the Shell Main Central Facility; however, because the McElmo Creek facility is located in a valley surrounded by higher terrain, it experiences poorer dispersion conditions than the other central facilities. Although onsite wind measurements show that the winds along the valley floor are usually channeled parallel with the mountains, they occasionally blow toward surrounding high terrain. Under such conditions, the pollutant plume might impinge upon the valley walls, resulting in high pollutant concentrations. The maximum 3-hour concentration resulting from worst-case meteorological conditions (described in Appendix A-3) would be 11 $\mu g/m^3$ for sulfur dioxide, well below the Colorado Category II incremental standard of 300 $\mu g/m^3$.

<u>Summary</u>

The air quality in the CO_2 well field would be temporarily degraded near activity during the construction phase of the project as a result of fugitive dust and gaseous emissions. These effects would be intermittent, transient, and would not affect regional air quality. Pollutant emissions during the operation of the CO_2 well field would affect a larger region over a longer time period than those emitted during construction. The effects would be relatively minor and well below state and federal air quality standards.

MAIN CO_2 PIPELINE

<u>Construction</u>

The construction phase of the main CO_2 pipeline would involve construction of an origin station, a compressor station, 9 communication towers, and the main CO_2 pipeline. Effects on air quality along the

proposed pipeline route would be similar to effects previously described for the CO_2 well field.

Fugitive dust and gaseous pollutant emissions have been calculated (using methods described in Appendix A-2) and are presented in Table 3-3. As in the vicinity of the CO_2 well field, the strong winds along the proposed route frequently cause high background particulate concentrations (see Chapter 2, Air Quality). Dust from construction activities would contribute to any violations of the federal standards that presently occur. Ambient gaseous pollutant concentrations along the route are low. The construction work would be spread over a large area and effects of the gaseous emissions would be minor and temporary.

Operation

Emissions due to pipeline operations would be negligible as the compressor located along the pipeline would be powered by an electrical motor. Some emissions would come from cars or trucks used during maintenance operations, but these would be very small.

Summary

For the duration of construction along the main CO_2 pipeline, air quality would be temporarily affected by fugitive dust and gaseous emissions. These emissions would be localized and would not affect regional air quality. The impact due to pipeline operation would be negligible.

OIL FIELD

Construction

Construction phase activities in the Wasson Oil Field would include construction of well facilities, booster compressor stations, a gas treatment plant, and flow lines. Effects would be similar to those previously described for emissions due to construction in the CO_2 well field. Emissions have been calculated using methods described in Appendix A-2 and are presented in Table 3-3.

Operation

During the tertiary oil-recovery process, emissions would be released by the compressors used to raise CO_2 to injection pressure. Table 3-3 gives estimated emissions for a 120,000 horsepower compressor facility, based upon assumptions documented in Appendix A-2. The compressors were assumed to use internal combustion engines burning low sulfur content ("sweet") natural gas. These compressors were also assumed to meet the proposed New Source Performance Standards for internal combustion engines. Because potential emissions of nitrogen dioxide and carbon monoxide would be greater than 250 tons per year, the facility would be required to obtain a PSD permit.

Annual concentration increments that would result from compressor operations were estimated from the modeling procedures described in detail in Appendix A-4. Exhaust gas release stacks were assumed to be high enough to avoid downwash eddies from the compressor shelters. The maximum annual concentrations were found to occur 600 meters north of the compressors. Annual average concentration increments of total nitrogen oxide (NO_x) are shown on Map 3-2. Because no onsite data were available, annual ambient concentrations of total nitrogen oxides (NO_x) and sulfur dioxide (SO_2) were estimated from average concentrations measured at Hobbs, New Mexico (30 miles southwest of the oil field) during 1976. These background concentrations (16 $\mu g/m^3$ of NO_x and less than 1.4 $\mu g/m^3$ of SO_2) were added to the computed increments to estimate maximum ambient concentrations expected to result from compresor operation. The maximum pollutant concentrations would be below state and federal air quality standards (Table 3-5).

As compressor emissions exit the stack, the nitrogen dioxide (NO_2) fraction is commonly only 10 to 25 percent of the total concentration of nitrogen oxides (NO_x); as the plume moves downwind, chemical reactions will increase this fraction. The rate of conversion is uncertain; 50-percent conversion times may range from 12 to 60 minutes (Davis et al. 1974). To assume that the maximum NO_x concentration would consist entirely of NO_2 (to which the ambient air quality standard applies) is a conservative view that overestimates maximum NO_2 concentrations. Concentrations decrease with distance; the maximum increment of NO_x at 2 kilometers would be 43 $\mu g/m^3$, or 55 percent of the maximum at 600 meters (Map 3-2).

Computed short-term maximum concentration increments of carbon monoxide, sulfur dioxide, and hydrocarbon for worst-case meteorological conditions would be below the relevant state and federal air quality standards (Table 3-6).

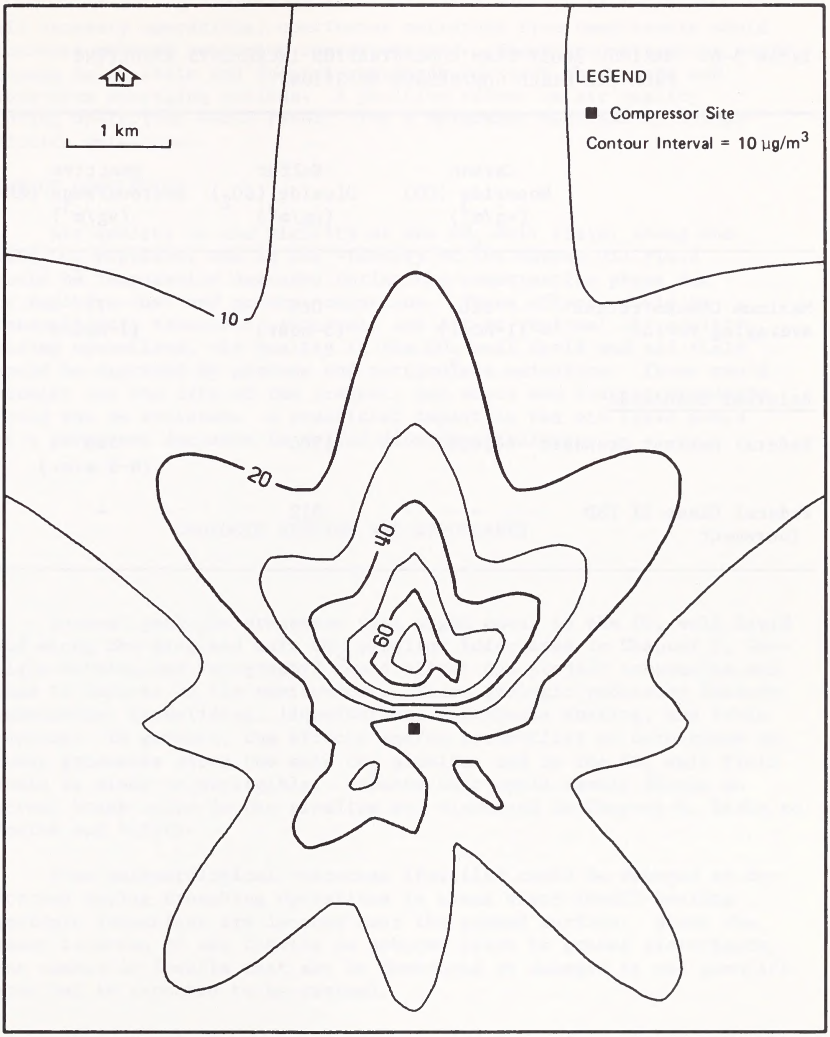
The proposed action would have one positive effect on local and regional air quality: a decrease in sulfur dioxide (SO_2) emissions, compared with existing emissions levels. Sulfur dioxide emissions would be reduced because a new hydrogen sulfide (H_2S) plant would produce sweet (low H_2S) gas, which when combusted would result in lower SO_2 emissions than the sour (high H_2S) gas currently being burned. As a result, annual emissions of sulfur dioxide would decrease from 24 tons per day prior to operation of the recovery plant (1983) to 20 tons per day after sulfur recovery has begun (1984). Gas production and sulfur dioxide emissions would decrease in subsequent years.

<u>Summary</u>

The air quality of the oil field would be temporarily degraded during the construction phase of the project as a result of fugitive dust and gaseous emissions. These effects would be intermittent, transient, and would not affect regional air quality. During tertiary

Table 3-5. MAXIMUM ANNUAL CONCENTRATIONS RESULTING FROM OIL FIELD COMPRESSOR EMISSIONS

	Total Nitrogen Oxides (NO_x) ($\mu g/m^3$)	Sulfur Dioxide (SO_2) ($\mu g/m^3$)
Maximum Annual Concentration Increment	78	0.04
Estimated Maximum Ambient Concentration	94	less than 1.4
Relevant Standards	Nitrogen Dioxide (NO_2) ($\mu g/m^3$)	Sulfur Dioxide (SO_2) ($\mu g/m^3$)
Federal Ambient Standard	100	80
Federal PSD Class II Standard	-	20



Map 3-2. ANNUAL CONCENTRATION INCREMENTS OF NITROGEN OXIDES FROM OILFIELD COMPRESSORS

Table 3-6. MAXIMUM SHORT-TERM CONCENTRATION INCREMENTS RESULTING FROM OIL FIELD COMPRESSOR EMISSIONS

	Carbon Monoxide (CO) ($\mu g/m^3$)	Sulfur Dioxide (SO_2) ($\mu g/m^3$)	Reactive Hydrocarbons (RHC) ($\mu g/m^3$)
Maximum Concentration Averaging Period	326 (1-hour)	0.3 (3-hour)	77 (3-hour)
<u>Relevant Standards</u>			
Federal Ambient Standard	40,000	1300	160 (6-9 a.m.)
Federal Class II PSD Increment	-	512	-

oil recovery operations, continuous emissions from compressors would increase ambient pollutant concentrations. These concentrations would remain below state and federal standards for both short-term and long-term averaging periods. A positive effect on air quality during operations would result from a permanent decrease in sulfur dioxide emissions.

IMPACT CONCLUSION

Air quality in the vicinity of the CO_2 well field, along the main CO_2 pipeline, and in the vicinity of the Wasson Oil Field would be temporarily degraded during the construction phase due to fugitive dust and gaseous emissions. These effects would be intermittent, transient, and would not affect regional air quality. During operations, air quality in the CO_2 well field and oil field would be degraded by gaseous and particulate emissions. These would persist for the life of the project, but state and federal standards would not be violated. A beneficial impact to the oil field would be a permanent decrease in sulfur dioxide emissions.

GEOLOGIC SETTING AND TOPOGRAPHY

Several geologic processes that might occur in the CO_2 well field and along the proposed main CO_2 pipeline (discussed in Chapter 2, Geologic Setting and Topography) could affect the project components and lead to impacts on the environment. These geologic processes include subsidence, landsliding, liquefaction, earthquake shaking, and fault rupture. In general, the effects and/or probability of occurrence of these processes along the main CO_2 pipeline and in the CO_2 well field would be minor to negligible. Impacts that could result should an actual break occur in the pipeline are discussed in Chapter 6, Risks to Health and Safety.

Some paleontological resources (fossils) could be damaged or destroyed during trenching operations in areas where fossil-bearing geologic formations are located near the ground surface. Since the exact location of any fossils is unknown prior to ground disturbance, the number of fossils that may be destroyed or damaged is not quantifiable but is expected to be minimal.

SOILS

CO_2 WELL FIELD

Construction

Removal of 2276 acres of vegetation during construction of access roads, drill pads, and gathering lines in the CO_2 well field would disturb the uppermost layer of soil in the affected areas. Although only a few inches of soil would be disturbed in most areas, the loss of protective vegetative cover would increase the rate of water- and wind-induced soil erosion. Calculations of wind-induced soil losses are not practicable; however, water-induced soil erosion losses for the cleared areas have been calculated using the methodology described in Appendix B.

The rate of water-induced soil erosion would be at a maximum during the period immediately after construction. This rate would be decreased by erosion control measures described in Chapter 1, Description of the Proposal Action, as well as by natural revegetation of some of the disturbed areas. Those disturbed areas to be occupied by buildings and maintained access roads would not begin to revegetate until after project termination some 30 years later. Because of increases in the existing rate of soil erosion, the total amount of erosion on cleared areas is estimated to be about 63,000 tons during the project life (Table 3-7). The increase attributable to the proposed project is estimated at 49,500 tons (an increase of approximately 270 percent in erosion on the disturbed areas).

Operation

Operation of the CO_2 well field would require no removal of vegetative cover that would result in additional increased erosion rates. Vehicle travel along access roads is expected to contribute only a minor increase to wind-induced soil erosion in the area. Thus the effects of CO_2 well field operation are expected to have only a minor impact on soils.

Summary

Construction and operation of the proposed facilities in the CO_2 well field would have a minor impact on soils in the area by increasing the rate of erosion. This increase (estimated at 49,500 tons for the life of the project) would be contributed by water-induced soil erosion resulting from vegetation clearance and disturbance of the upper soil layer at construction sites. Wind-induced soil losses are anticipated to be minor.

Table 3-7. ESTIMATED SOIL LOSSES DUE TO WATER-INDUCED SOIL EROSION*

Project Element	Estimated Soil Loss Without Project (tons)	Estimated Soil Loss With Project (tons)	Difference Attributed to Project (tons)
CO_2 Well Field	13,500	63,000	49,500
Main CO_2 Pipeline	5,800	15,400	9,600
Oil Field	13,600	63,400	49,800
TOTAL	32,900	142,000	109,100

*See Appendix B for methodology.

MAIN CO_2 PIPELINE

Construction

As in the CO_2 well field, removal of vegetative cover would be the major source of erosion increase to impacted soils. Erosion along the right-of-way clearing (until revegetation is completed) is estimated at 15,400 tons, or about a 170-percent increase in the natural rate of erosion (Table 3-7). The impact of this erosion increase (9600 tons) on soils in the pipeline region is expected to be minimal since the loss in any one area would be relatively insignificant due to the narrow width of the right-of-way.

Operation

Operation of the main CO_2 pipeline is not anticipated to increase soil erosion rates or to result in any additional impact to soils.

Summary

Construction and operation of the proposed pipeline would have a minor impact on soils primarily as a result of increasing the water-induced soil erosion by a cumulative total of 9600 tons. This loss would result from removal of protective vegetative cover and would continue until the cleared areas became revegetated.

OIL FIELD

Construction

Construction activities in the oil field would have the minor impact of accelerating the natural rate of soil erosion by removing the vegetative cover and disturbing the upper soil layer. Water-induced soil erosion on disturbed areas resulting from proposed activities in the oil field is estimated at 63,400 tons until disturbed areas revegetate (Table 3-7). This represents an increase of approximately 370 percent (49,800 tons) in soil loss on the affected area, a small amount when compared with soil loss for the entire oil field.

Operation

Operation of the oil field may contribute slightly to wind-induced erosion in the oil field as a result of vehicle traffic on unpaved access roads. This increase is expected to have a negligible impact on soils in the oil field.

Summary

Construction and operation of the oil field would result in the loss of an additional estimated 49,800 tons of soil due to water-induced

erosion and an unquantifiable but minor loss of soil due to wind-induced erosion. These losses are considered minor compared with existing rates of soil loss in the oil field due to erosion.

IMPACT CONCLUSION

Construction and operation of the proposed project would have a minor impact on soils resulting from removal of vegetative cover and disturbance of the upper soil layer at construction sites. This loss is estimated to total 109,100 tons, or 330 percent above the expected soil loss, from water-induced soil erosion during the life of the project and/or until the cleared areas revegetate.

WATER RESOURCES

CO_2 WELL FIELD

Construction

Groundwater. Construction of the proposed CO_2 well field should have no significant impacts on local groundwaters. Cross-contamination of higher quality aquifers by saline waters present in some of the strata to be penetrated may occur during CO_2 well construction. However, several construction techniques to be used (e.g., cementing the surface casing) (see Chapter 1, Description of the Proposal) should drastically reduce the probability of such an occurrence.

Surface Water. Approximately 39 miles of newly constructed new access roads to the CO_2 well pads could cause local alteration of some surface drainage patterns. This would tend to be more pronounced in areas of steep topography than on the mesas. Erosion potential would increase and intermittent streams or washes within the CO_2 well field would experience increased suspended sediment loads during intense rainstorms. These sediment-laden waters discharge into either the Dolores River or McElmo Creek; thus the potential exists for increased sediment loads in these streams during intense storms. The resulting impact would be minor, however, since the receiving waters carry naturally high sediment loads during intense rainstorms. Estimates of this project-related sediment load (Table 3-8) indicate that it would increase existing instream sediment levels by less than 1 percent.

Drilling operations would involve construction of a drill pad and mud pit, which could cause local alteration to some surface drainage patterns and increase erosion potential. Such construction operations could have an indirect impact on the water quality in the Dolores River and in McElmo Creek by increasing their sediment loads during periods of heavy rainfall, as discussed above.

Table 3-8. IN-STREAM SEDIMENT LOAD PREDICTIONS

Stream	Maximum Annual Project-Related In-Stream Load (tons)	Increase Above Existing Annual In-Stream Load (%)
Dolores River	56	0.10
McElmo Creek	167	0.30
Mancos River	24	0.06
La Plata River	24	0.07
Animas River	29	<0.01
San Juan River	88	<0.01
Rio Grande	75	<0.01
Pecos River	55	0.02

Note: In calculating the above in-stream load values, soil loss predictions presented in Chapter 3, Soils, were multiplied by 0.10 (a delivery ratio of 10 percent). Because of the nature of the drainages through which the project passes, this delivery ratio is considered to be conservative and to constitute a worst-case analysis.

Installation of the 192 miles (1152 acres) of wet-CO_2 gathering lines and the 126 miles (756 acres) of dry-CO_2 gathering lines would have little impact on surface water. The dry-CO_2 pipeline system would, however, cross the Dolores River and McElmo Creek. Construction equipment would be needed for work in the stream beds at these crossings. The impact of this construction activity is expected to be limited to temporary disruption of stream channels, causing increased in-stream sediment loads. While suspended sediment levels in the immediate vicinity of the crossing could be increased substantially (based on various field studies [Schubel et al. 1978, Renard 1972, Wolman et al. 1967], in-stream levels could easily double), this increase would drop rapidly as the load traveled downstream. Within several thousand feet downstream of the crossing, in-stream suspended sediment levels would approach pre-crossing levels (see Figure 3-1).

In addition, the gathering lines at stream crossings would be hydrostatically tested using approximately 0.5 acre-foot of fresh water obtained from nearby wells and streams. This test water would be discharged in accordance with applicable federal, state, and local regulations.

The 13 central facilities would be constructed on 5-acre sites. Little impact on the surface and groundwater of the area is anticipated, though some increase in erosion potential can be expected. Similarly, construction of the electric power transmission lines would have some, though minimal, impact on surface hydrology by increasing the erosion potential.

Operation

Groundwater. Operation of the proposed CO_2 well field would have no significant impact on local groundwaters.

Surface Water. The potential for impact on surface water resources of the CO_2 well field during project operation is limited. The most probable source of impact would arise from accidental release of contaminants caused as a result of equipment failure or malfunction. Spills into the environment could take place at any of the 13 central facilities where fuel oil was stored in tanks within diked areas. Such a spill could impact the local waterways should the fuel tank rupture during a period of high rainfall or during dike failure. However, the probability of a tank rupture occurring simultaneously with a heavy rainfall or a dike failure is low.

Summary

Based on the above analysis, the construction and operation of the proposed CO_2 well field would have no major impacts on the water resources within the project area.

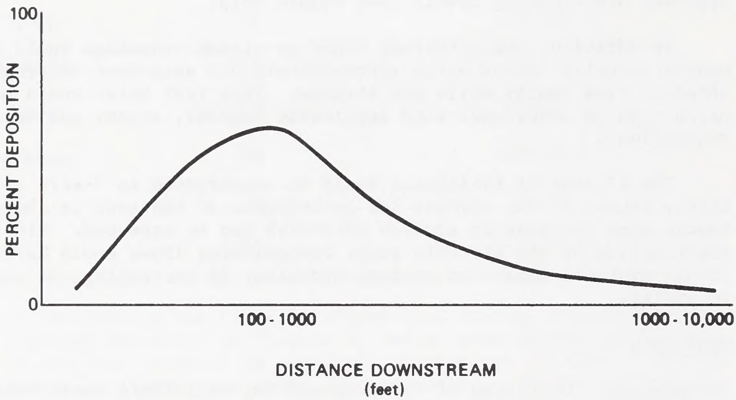


Figure 3-1. INITIAL DEPOSITION OF SUSPENDED SEDIMENT DOWNSTREAM FROM A COSTRUCTION SITE

MAIN CO_2 PIPELINE

Construction

Groundwater. Construction of the main CO_2 pipeline would have no significant impact on the groundwaters that underlie the proposed pipeline route.

Surface Water. The main CO_2 pipeline would cross six major streams (San Juan, Mancos, La Plata, Animas, Rio Grande, and Pecos rivers) and many intermittent streams, washes, and arroyos. Construction of the major stream crossings would result in increased sediment loads downstream of those crossings during the 1- to 3-day period required to construct each crossing. The "area of influence" over which these heightened suspended sediment levels were felt would depend on the nature and quantity of sediment disturbed by the construction as well as the flow rate of the stream disturbed. Based on field studies from diverse areas (Schubel et al. 1978, Renard 1972, Wolman et al. 1967), the distance downstream that this sediment load would travel is generally defined by a normal distribution (Figure 3-1). The deposition peak typically occurs within the first 1000 feet downstream from the point of construction; however, this distance can be reduced to less than 100 feet if the dominant particle size of the material suspended is greater than 0.4 mm in size.

The time duration of these heightened suspended sediment levels is likewise dependent on particle size and the velocity of receiving water. In most instances, the point of peak deposition would occur in less than one hour, though somewhat heightened levels can obviously last much longer. Thus, in general, the impacts attributable to construction in various water courses would be both transitory in nature and limited in extent (i.e., time and distance of influence).

Specific in-stream sediment increases attributable to pipeline construction were estimated using the projected soil loss data contained in Chapter 3, Soils. Assuming a delivery ratio of 10 percent (Roehl 1962 and Mutchler et al. 1972), it was found that on an annual basis construction activities would never increase the existing suspended sediment levels presented in Chapter 2, Water Resources, by more than 1 percent (Table 3-8). For example, the estimated increases ranged from less than 0.01 percent in the San Juan River to 0.3 percent in McElmo Creek. Moreover, a 10-percent delivery ratio for the entire pipeline length is probably greater than the actual value, since the bulk of the pipeline is not located in close proximity to perennial streams (i.e., with the exception of the above-mentioned major stream crossings, most of the area traversed by the pipeline is drained by only intermittent streams). Thus the preceding values would constitute a worst-case analysis for the annual project-related sediment load.

To hydrostatically test the main CO_2 pipeline, 12 to 24 acre-feet of water would be required, a quantity that should not impact local supplies. Similarly, while some contamination of the surface hydrological regime could be expected due to this water's discharge (e.g., construction debris, millscale, and small amounts of hydrocarbons), no discharges would be allowed until all state/federal regulations had been met.

Installation of the communication towers along the route would have a minor impact on drainage patterns, and a minor increase in erosion potential can be expected.

Operation

Groundwater. No significant impacts to groundwater resources would result from the operation of the proposed CO_2 pipeline.

Surface Water. An increased erosion potential would be expected along the pipeline corridor until the disturbed areas became revegetated. Increased erosion would lead to increased sediment loads in major streams during periods of high runoff. As described in Chapter 2, Water Resources, these periods generally occur in the late spring and during summer and fall thunderstorms; however, since natural sediment load of major streams is high during periods of high runoff, the impact would be minor. Estimates of the suspended sediment levels attributable to project operation indicate that it would increase existing in-stream levels by 1 percent or less on an annual basis for all of the streams crossed by the pipeline (Table 3-8).

Operation functions that involve excavation of the buried main CO_2 pipeline, maintenance of the erosion control structures along the rights-of-way, or other earth moving activities could temporarily alter surface drainage in the immediate work area. The effects would be localized and should be noticeable only during periods of high runoff. No significant alteration of surface hydrology should occur.

Should a pipeline leak occur at one of the major river crossings, CO_2 could be released to the streams. A continual release of CO_2 to a body of water could cause a lowering in pH and possibly induce some precipitation of compounds, though the natural buffering capacity of these waters (the carbonate system) should limit the severity of any pH change.

Summary

Though suspended sediment loads in the water courses crossed by the project would be increased, these increases would generally be limited to relatively small areas. Thus the construction and operation of the main CO_2 pipeline would not be expected to have any major impacts on the water resources of the project area.

OIL FIELD

Construction

Because only minor construction would be required to connect the oil field to the proposed CO_2 system, no significant impacts on water resources, either surface or ground, are expected.

Operation

Groundwater. Because of the water quality characteristics of the Denver Unit, and because it is already a fully developed oil field, the impacts on its groundwaters would be slight. As part of the existing waterflood program, the original high salinity formation water is being altered by injection of relatively fresh water; this results in a lower overall salinity in the formation. Injections of CO_2 into the same formation would decrease the pH of this brine and create a mild carbonic acid (the amount of waterflooding involved would remain unchanged). The total solids content of the brine would remain lower than that of the original formation water; thus the impact is considered minor.

Surface Water. No significant surface water impact would result from the operation of the oil field with CO_2 injection.

Summary

Construction and operation of new facilities in the oil field would have no major impacts on the water resources of the project area.

IMPACT CONCLUSION

While the proposed project could conceivably result in a number of water-related impacts (e.g., aquifer cross-contamination in the well field, water consumption and subsequent wastewater discharge, accidental spills), judicious planning has reduced the likelihood of these impacts to very low levels. The only impacts source not reduceable to negligible levels is the erosional and sedimentation effects attributable to pipeline construction. Such construction would increase local in-stream suspended sediment levels during the construction period, but the amount of increase would be relatively minor and should not have a major impact on the beneficial uses of these waters.

VEGETATION

CO_2 WELL FIELD

Construction

Terrestrial and Riparian. Construction of the well field facilities would require clearing vegetation over about 2276 acres (approximately 0.7 percent) of the CO_2 well field (Table 3-9). Clearance of an average 50-ft width of the wet-CO_2 gathering lines (including adjacent access roads when present) and dry-CO_2 gathering lines accounts for about 85 percent of the total acreage of vegetation disturbance. About 45 percent of the total vegetation acreage to be cleared is in agricultural areas; 37 percent is in pinyon-juniper and chained pinyon-juniper vegetation types; less than 6 percent is forested. Disturbance to riparian vegetation would be minimal since no wells or central facilities would be placed in this vegetation type. A small amount (about 3 acres) of riparian vegetation may be cleared at access road and gathering line crossings.

Vegetation clearing in the CO_2 well field would primarily take place from 1980 to 1984. Revegetation procedures would be initiated following construction activities in each affected work site over about 2057 acres (90 percent) of the cleared ground (Table 3-9). The remaining 219 acres (10 percent) would be occupied by operation facilities such as buildings and access roads for the 30-year life of the project.

Revegetation success would vary depending on several factors including the types of vegetation and soils affected. Revegetation would be most successful on 945 acres (41 percent) of the area occupied by agricultural lands (excludes 73 acres of building sites and access roads) since these areas could be returned to productivity within about one year. Revegetation would take longer on nonagricultural lands with success varying from good to poor. Revegetation success would generally be greatest on affected areas with adequate topsoil where surface disturbances were minimal (such as on level well sites and gathering lines). Revegetation would be least successful in areas with minimal or no soil layer, steep terrain subject to erosion, and/or major soil disturbances during construction. Revegetation success is expected to be fair to poor in areas having minimal or no vegetative cover prior to construction disturbance. The relatively small size of cleared areas in any one location would generally enhance revegetation processes since seed sources and plants that spread via rhizomes (underground stems) or other methods usually exist in adjacent undisturbed areas.

Revegetation time schedules for disturbed areas involving native vegetation types are more difficult to estimate due to variations of soil type and depth, the arid climate, unpredictable timing and intensity of

Table 3-9. ESTIMATED VEGETATION DISTURBANCE (in acres)

	CO_2 Well Field			Main CO_2 Pipeline			Oil Field			Total		
Vegetation Type	Total Disturbance	Revegetated after Construction	Committed	Total Disturbance	Revegetated after Construction	Committed	Total Disturbance	Revegetated after Construction	Committed	Total Disturbance	Revegetated after Construction	Committed
Ponderosa pine forest[b]	139	110	29	109	109	-	-	-	-	248	219	29
Aspen woodland[c]	-	-	-	-	-	-	-	-	-	-	-	-
Mountain grassland[c]	-	-	-	-	-	-	-	-	-	-	-	-
Pinyon-juniper woodland	679	602	77	286	285	1	-	-	-	965	887	78
Chained pinyon-juniper shrubland	184	154	30	-	-	-	-	-	-	184	154	30
Sagebrush	107	98	9	461	449	12	-	-	-	568	547	21
Desert shrub	146	145	1	15	15	-	-	-	-	161	160	1
Shinnery	-	-	-	55	55	-	-	-	-	55	55	-
Desert grassland	-	-	-	1296	1294	2	-	-	-	1296	1294	2
Plains grassland	-	-	-	554	551	3	1295	1140	155	1849	1691	158
Riparian	3	3	-	10	10	-	-	-	-	13	13	-
Agriculture	1018	945	73	194	189	5	-	-	-	1212	1134	78
Total	2276	2057	219	2980	2957	23	1295	1140	155	6551	6154	397

[a]Estimate of amount of land that would be committed for the 30-year project life.
[b]Includes mountain shrub vegetation type.
[c]Vegetation type present in the CO_2 well field but not in areas to be disturbed.

precipitation events, and other factors. The general time schedules discussed below have been determined from applicable revegetation studies (such as Ludwig et al. 1977, Barney and Frischkaecht 1974, Jones and Trujillo 1975, and Schantz 1917) and from observations of revegetation success on similar types of disturbances in comparable vegetation types.

Weedy species would be expected to invade disturbed areas during the first 1 to 2 years after construction disturbances were completed. This vegetation would gradually be replaced by more desirable grasses and forbs during the period ranging from 3 to 5 years after construction. After 15 years (or less) of the original disturbance, native species would have increased to where they resembled the predisturbance understory in abundance and species composition, provided the area was not redisturbed. Successful reseeding of grasses and forbs tends to minimize the weedy stage so that desirable species may become established within 1 or 2 years; within 5 years, these species may attain cover values approaching 50 to 80 percent of predisturbance cover values.

Shrub seedlings may become established within 5 years following construction, but generally require 5 to 15 years to attain heights and cover values that resemble undisturbed shrubs of adjacent areas. Trees may require 30 to 50 years or longer to become successfully established on disturbed areas.

Based on this revegetation time schedule, it is estimated that herbaceous ground cover would begin to appear on 1112 acres (88 percent of the nonagricultural disturbed areas) of the CO_2 well field within about 1 to 2 years of construction disturbances except in extremely dry, unproductive sites.

Shrub and tree species would be expected to take about 5 years or more to become established and from 15 (for shrubs) to over 50 years (for trees) to form an overstory similar to that in undisturbed areas.

Loss of vegetation on cleared areas would result in impacts on livestock, wildlife, recreation, aesthetics, soil, and water until vegetation became reestablished (see Chapter 3, related sections). The impact of vegetation removal on vegetation communities or types within the CO_2 well field would be minimal since the disturbance would involve only about 0.7 percent of the CO_2 well field and would be almost completely confined to the actual area cleared (i.e., dust or exhaust emissions or other pollutants are not expected to cause any detectable damage to adjacent vegetation). The loss of plant biomass and productivity from cleared areas would be considered minimal in terms of the total biomass and productivity of each vegetation type in the CO_2 well field. Assuming that biomass and productivity of vegetation are proportional to acreage involved, then the total loss of plant biomass and productivity for disturbed areas can be estimated at a maximum of 0.7 percent of that for the well field immediately after construction, and less in subsequent years as revegetation

occurs. Losses of this magnitude are considered insignificant since plant productivity typically varies each year by 25 to 35 percent of the median yearly value, depending primarily on precipitation (U.S. Soil Conservation Service 1975).

Aquatic. Apart from access roads and gathering lines, no project facilities would be placed in streams, creeks, or ponds. Construction of access roads and gathering lines across the Dolores River, McElmo Creek, and Yellowjacket Creek would increase the level of sediments in the streamflow a few thousand feet downstream of the construction site for 1 to 3 days (see Chapter 3, Water Resources). The impact of any increased sediments on aquatic vegetation is expected to be minimal.

Endangered and/or Threatened Plant Species. The proposed construction activities would not impact any endangered or threatened plant species since no plant species on the present list occur in Colorado or the Four Corners region. It is possible that some species on the list of proposed species could be affected if any individuals were present in areas to be disturbed. The significance in that case would depend primarily on the percent of the population lost. Since disturbances in any one area would be small (1.9 acres for each drill pad, 5 acres or less for each of 13 central facilities), the loss of a large portion of any population would be unlikely.

Operation

Terrestrial and Riparian. Operation of the CO_2 well field would require no additional removal of vegetation. The major effect of CO_2 well field operation would be to prevent revegetation processes during the 30-year operational life on the access roads, well facilities, and central facilities. Since these areas involve only 219 acres, or less than 0.07 percent of the CO_2 well field, operational impacts on the terrestrial and riparian vegetation are considered minimal. Similarly, secondary impacts to vegetation as a result of dust, engine emissions, and increased human activity are expected to have a minimal effect on the adjacent vegetation and a negligible impact on the vegetation in the CO_2 well field.

Aquatic. Operation of the CO_2 well field is expected to have no direct impact on aquatic vegetation in the vicinity of the CO_2 well field. Similarly, any indirect impacts as a result of erosion or other causes are considered minimal due to the erosion control measures discussed in Chapter 1, Proposed Action.

Endangered and/or Threatened Plant Species. The operation of the CO_2 well field is expected to have no impact on endangered or threatened plant species (listed or proposed).

Summary

Construction and operation of the CO_2 well field would result in removal of approximately 2276 acres of vegetation. Of this amount, about 945 acres (41 percent) is agricultural land that could be returned to productivity within approximately 1 year of construction completion. Herbaceous vegetation is expected to begin appearing on approximately 1112 acres (49 percent) of the disturbed area within 1 to 5 years; shrubs within 5 to 15 years. About 10 percent (219 acres) of the disturbed area would be occupied by buildings, access roads, etc., and would remain disturbed for the 30-year operational life of the project. These facilities (except for perhaps some roads that the surface management agency would maintain permanently) would then be removed and reclaimed.

MAIN CO_2 PIPELINE

Construction

Terrestrial and Riparian. Construction of the proposed 478-mile pipeline and associated facilities (origin station, compressor station, and microwave stations) would disturb an estimated 2980 acres, or about 4.7 square miles, of vegetation (Table 3-9). Removal of vegetation along the pipeline right-of-way would account for nearly 97 percent of the disturbance to vegetation during construction of the main CO_2 pipeline system. Vegetation would be removed from an estimated average 50-ft width within the 100-ft right-of-way to allow sufficient work space for machinery and vehicles.

Although nine major vegetation types would be affected, approximately 2044 acres (69 percent) of the vegetation disturbance would be confined to the grassland and agriculture vegetation types. About 531 acres (18 percent) of the vegetation disturbance would occur in shrublands, 286 acres (10 percent) in woodlands, 109 acres (4 percent) in forested areas, and about 10 acres (less than 1 percent) in riparian vegetation.

Vegetation disturbances would occur primarily during 1981, when construction would be at its peak. Reclamation procedures along the right-of-way would begin on over 99.3 percent (2957 acres) of the disturbed area immediately after construction is completed at each work site. The remaining disturbed area (23 acres) would be associated with land occupied by the origin station, compressor station, and microwave sites. Vegetation reestablishment would take from 1 to over 50 years, depending on local conditions and the vegetation type present before construction. Agricultural areas disturbed along 189 acres (6 percent) of the right-of-way could be returned to productivity within 1 year after construction was completed. On the remaining

2768 acres to be reclaimed, herbaceous species would begin to appear on disturbed areas within 1 to 2 years. Where surface management agencies (on federal lands) or private landowners required seeding as a reclamation procedure, the herbaceous vegetation would likely include desirable grasses and forbs as well as invading species characteristic of initial succession stages. Seedlings of woody species such as shrubs and trees (depending on the preconstruction vegetation type) could appear in about 3 to 5 years but may take 5 to 15 years (for shrubs) or over 50 years (for trees) to grow to heights resembling similar species in adjacent undisturbed areas.

Revegetation of areas disturbed during pipeline construction should be most successful in the grassland vegetation type since herbaceous species , which grow to maturity in only 1 to 2 years, are dominant. Revegetation would be least successful on areas along the pipeline route where local conditions (e.g., limited topsoil horizon, high salt content) may have resulted in an extremely sparse vegetative cover prior to construction. In such areas, it is probable that any vegetation reestablishment would also be sparse.

The potential for natural revegetation of the right-of-way is generally high since surface soil disturbances would not be severe in most areas and stockpiled topsoil would be replaced. Also, the narrow width of the right-of-way would likely enhance the establishment of plant species from adjacent undisturbed areas. The degree of natural establishment of native plants in a disturbed area by seed dispersal and/or rhizomes and spreading roots is related in part to the ratio of the perimeter to the total area of disturbance. A large perimeter in relation to area, as would be the case with the pipeline right-of-way, provides a larger number of plants as potential sources for seeds, rhizomes, and spreading roots. The perimeter of the right-of-way is over 125 times longer (956 miles versus 7.5 miles) than the circumference of a circle having the same area.

In addition to a change in plant species composition, removal of vegetation along the pipeline right-of-way and associated facilities would cause a reduction in the vegetation biomass and annual productivity of the region. Vehicular emissions during construction and fugitive dust during and after construction would settle on vegetation in adjacent undisturbed areas but is not expected to cause any discernible changes to the species composition, biomass, or annual productivity of adjacent vegetation.

Vegetation loss along the pipeline right-of-way and associated facilities would result in impacts on wildlife, livestock, recreation, aesthetics, soil, and water (see Chapter 3, related sections) until revegetation occurred. Potential impact to vegetation communities as a result of removing 2980 acres of vegetation is considered minimal since the resulting loss of plant biomass and annual productivity is

expected to be negligible (less than 1 percent) compared with total biomass or annual productivity of any valley, mountain, or watershed affected by the pipeline.

Aquatic. Construction of the pipeline and associated facilities would have a direct effect on aquatic vegetation at major river crossings. The removal of terrestrial and riparian vegetation during construction would also have an indirect effect on aquatic vegetation in streams as a result of increased erosion. The effect of construction on aquatic vegetation at river crossings would be minimal due to the small area involved and the amount of sediment generated at the construction site that would be carried downstream.

Endangered and/or Threatened Plant Species. Construction of the proposed main CO_2 pipeline would have no impact on endangered or threatened plant species since no plant species on the federal list are known to occur in Colorado, New Mexico, or West Texas. Plant species currently being reviewed for inclusion on the federal list could be affected if any plants were present on areas disturbed during construction.

Operation

Terrestrial and Riparian. Operation and maintenance of the pipeline system would require no additional removal of vegetation. The major effect on terrestrial and riparian vegetation as a result of pipeline system operation would be the prevention of revegetation during the 30-year operational life on the 23 acres of land occupied by the origin station, compressor station, and microwave sites.

Because routine pipeline inspections would be conducted by aircraft, no permanent access road would be needed along the right-of-way. Vegetation would be disturbed only during pipeline operations when necessary for pipeline repair. Thus operational impacts to vegetation along the right-of-way are predicted to be negligible.

Clearance of the right-of-way would make some areas more accessible than previously to off-road vehicles. Continued use of the right-of-way by off-road vehicles could result in additional destruction of vegetation as well as hinderance of the revegetation process. These vegetation losses are expected to be minimal since most of the pipeline route parallels existing utility corridors rather than crossing previously inaccessible areas. Periodic gates and fences are also expected to reduce off-road vehicle travel along the right-of-way.

Aquatic. No impact on aquatic vegetation is expected from operation or maintenance of the pipeline system.

Endangered and/or Threatened Plant Species. Operation and maintenance of the pipeline system would not disturb any additional vegetation

and so would have no impact on any existing or proposed endangered or threatened plant species.

Summary

The construction and operation of the proposed main CO_2 pipeline would result in the removal of an estimated 2980 acres of vegetation. Reclamation would follow construction on all but 23 acres of the disturbed area. About 6 percent (189 acres) of the disturbed area would consist of agricultural lands that would be returned to crop production within 1 year. Herbaceous species would appear on much of the remaining 2768 acres within 1 or 2 years, though shrub heights and densities may not approach preconstruction levels for 5 to 15 years. Trees may take 50 years or more to resemble preconstruction conditions.

Construction and operation of the pipeline system are expected to have no impacts on endangered or threatened plant species.

OIL FIELD

Construction

Terrestrial and Riparian. Construction of about 100 new injection and/or producing wells and other facilities (gathering lines, flow lines, compressor stations, etc.) at the Denver Unit of the Wasson Oil Field would result in the removal of 1295 acres of plains grassland vegetation (Table 3-9). Revegetation on 1140 acres (88 percent) of the disturbed area would begin following construction in each work area. Herbaceous vegetation is expected to appear within 1 or 2 years; however, about 5 to 15 years may be required before vegetation on disturbed areas would resemble the species composition and ground cover present prior to construction. Disturbed areas on 155 acres occupied by buildings and access roads would not be allowed to revegetate until project termination.

Emissions from construction equipment, vehicles, and other sources as well as fugitive dust are not expected to result in any detectable changes in species composition, biomass, or annual productivity of adjacent vegetation.

The impact on the vegetation of the Denver Unit region from construction disturbances in the oil field is expected to be minimal in view of the small number of acres involved and the short time required for revegetation.

Aquatic. Construction of the oil field facilities is expected to have no impact on aquatic vegetation due to the absence of aquatic habitat in the oil field and vicinity.

Endangered and/or Threatened Plant Species. Because no endangered or threatened (or proposed) plant species are expected to occur in the oil field area, no impact is expected from construction of additional facilities in the area.

Operation

Terrestrial and Riparian. Operation of the oil field facilities would require no additional clearing of vegetative cover. As during construction, emissions from compressors and vehicles as well as fugitive dust are expected to result in no detectable changes in the adjacent vegetation. Since access roads are present, minimal damage to vegetation by off-road vehicles is expected. The changes to area vegetation as a result of oil field operations are estimated to be minimal; such changes should result in no significant impacts to terrestrial vegetation present in the oil field vicinity.

Aquatic. Oil field operation is expected to have no impact on aquatic vegetation due to the lack of aquatic habitat in the oil field area.

Endangered and/or Threatened Plant Species. Operation of the oil field facilities is expected to have no impact on any endangered or threatened plant species since none are known to occur in the oil field area.

Summary

Construction and operation of the additional oil field facilities (injection and producing wells, access roads, pipelines, compressor stations, etc.) would result in the removal of an estimated 1295 acres of plains grassland vegetation. About 1140 acres would be allowed to revegetate upon completion of construction; the remaining 155 acres occupied by access roads, equipment, and buildings would be allowed to revegetate at project termination about 30 years later. Vegetation is expected to appear on disturbed areas within 1 or 2 years. Five to 15 years may be required for shrub species to become established and attain heights resembling preconstruction conditions.

The absence of any known endangered or threatened (or proposed) plant species in the oil field vicinity precludes the possibility of impact to these species.

IMPACT CONCLUSION

Construction and operation of the proposed project (CO_2 well field, pipeline, and oil field) would result in the temporary loss of 6551 acres of vegetation. Reclamation including revegetation would be initiated on 6154 acres (94 percent) immediately following construction in each area. The remaining 397 acres (6 percent) disturbed during construction would be occupied by access roads, equipment, and buildings. Reclamation would be initiated in these areas after project termination.

FISH AND WILDLIFE

Construction and operation of the proposed CO_2 project are expected to have some impacts on the fish and wildlife in or near the project area. These impacts generally would result from the following causes:

- loss of habitat and associated carrying capacity
- direct loss of individuals in the population
- degradation of habitat due to increased human activity and noise

CO_2 WELL FIELD

Construction

Fish. Impacts to fish by construction of new facilities (wells, access roads, gathering lines, central facilities, etc.) are expected to be minimal due to the small amount of aquatic habitat disturbed, the season of construction, and the temporary nature of construction. Approximately 200 feet of stream bank would be directly affected at each pipeline or access road construction site at the Dolores River and McElmo Creek (see Chapter 2, Water Resources).

Construction activities at stream crossings would cause increased erosion and siltation by altering stream banks, removing streamside vegetation, and disrupting the bottom during ditching. Increased suspended sediments at the crossing and for a few thousand feet downstream for 1 to 3 days after construction could reduce the growth of phytoplankton and aquatic plants and cover bottom-dwelling organisms and spawning beds.

At the Dolores River pipeline crossing, some trout and other fish species could be lost due to blasting, if it were required, or due to increased suspended sediments. These losses are expected to be minimal in view of the area affected and time period involved. Any losses that might occur to fish or other aquatic organisms are not expected to result in significant impacts to fish populations of the Dolores River.

At the pipeline and access road crossings of McElmo and Yellowjacket creeks, similar temporary changes are expected to occur at and downstream from the proposed crossings. As with the Dolores River, these losses would be minor and are not expected to result in a significant impact to fish populations in these creeks.

Wildlife. Construction of access roads, wells, buildings, gathering lines, and other facilities would result in the loss of approximately 2276 acres of wildlife habitat and an associated reduction in carrying capacity. Some individual animals, especially the smaller vertebrates,

would be unable to move to another area and would be destroyed during land clearing operations. Other animals in adjacent areas may be affected by construction noises or by increased human activity. Construction effects and the resulting impacts to specific wildlife populations in the area are discussed below.

Large Mammals. Large mammals (e.g., mule deer, elk, black bear, and mountain lion) that occur in the CO_2 well field vicinity should not be significantly affected by habitat losses due to construction. The 1258 acres of big game habitat (nonagricultural lands) that would be destroyed during clearing of access roads, pipeline rights-of-way, and building sites are estimated to be less than 1 percent of the summer or winter range for affected populations of each of these species. Less than 25 acres of crucial elk and mule deer winter range would be temporarily removed during construction of the dry-CO_2 gathering line between the Doe Canyon East Central Facility and Dolores Canyon. No well sites are located within a mile of any crucial winter range. The temporary loss of crucial winter range along a pipeline right-of-way is likely to have a negligible impact to elk and mule deer.

Although most large mammals would avoid cleared areas during construction periods, they are not expected to maintain permanent buffer zones around each disturbed area. Mule deer and elk would be attracted to the revegetated areas to eat grasses and smaller shrubs in preference to larger shrubs and small trees of adjacent undisturbed areas.

Increased noise levels as a result of construction activities would cause some large mammals to leave the immediate area of the noise source; however, the actual number displaced is expected to be relatively small (estimated at less than 1 percent of the area population). Many large mammals tend to adjust to construction noises so that the actual effects become less with repetitive exposure.

Increased human activity in the area would cause some large mammals to leave the immediate area, as well as to cause some amount of habitat deterioration in the CO_2 well field. Although this increased activity could also result in some animal fatalities as a result of road kills, the actual number of animals lost is expected to be relatively minor when compared with population levels in the area.

Medium- and Small-Sized Mammals. Some medium- and small-sized mammals would be lost or displaced during ground clearing operations. Although densities for some animals such as the deer mouse may be relatively high, the actual number of medium- and small-sized mammals is estimated to be less than 1 percent of the total area population. The small amount of habitat destroyed, the high reproductive rate, and the rapid population turnover for many of these animals is expected to result in rapid repopulation in most disturbed areas as vegetation becomes

reestablished. Thus the impact of project construction on populations of medium- and small-sized mammals in the vicinity of the well field is considered minimal.

Birds. Loss of habitat could affect game birds (e.g., Gambel's quail, ring-necked pheasant, turkey, and mourning dove) but any losses are likely to be minimal in terms of population size. Removal and destruction of grasses, shrubs, and trees from 2276 acres (including agricultural lands) of the CO_2 well field would reduce food sources in the immediate area of disturbance but would not measurably reduce the food sources of the total CO_2 well field vicinity.

Construction of the CO_2 well field facilities would not directly affect a significant amount of waterfowl habitat. Small lakes, reservoirs, or ponds would not be selected as construction sites. Stream crossing sites on the Dolores River and McElmo and Yellowjacket creeks provide no extensive waterfowl resting, nesting, or feeding areas. As a result, construction impacts to waterfowl in the CO_2 well field are expected to be minimal.

Birds of prey in the vicinity of the CO_2 well field may be affected by the loss of habitat as well as increased noise levels and human activity. The loss of habitat and associated prey species (small mammals, birds, reptiles) is considered minimal when compared with the large area that birds of prey generally utilize. Loss of nesting habitat on cliff faces would also be minimal since, for engineering purposes, most of the construction sites do not include cliff faces. The designated prime habitat for peregrine falcons would not be impacted since none of the CO_2 well field facilities are located in this area of Dolores Canyon.

Increased noise levels (from blasting and other construction activities) as well as increased human activity at construction sites and in the CO_2 well field vicinity in general would cause some habitat deterioration for birds of prey during the construction period. Noise and human activity at the construction sites may cause some birds to abandon nearby nests (generally within 1/4 mile of a construction site) or may cause a disruption of breeding activities. The probability of such disruptions would be greatest during 1981 and 1982 when construction activity would be at its highest in the vicinity of the CO_2 well field. Raptor nests more than 1/4 mile from any construction site would probably not be affected.

These temporary effects are expected to have a minimal impact on the populations of the more common raptor species, such as the red-tailed hawk, screech owl, or great horned owl. Although any losses to the peregrine falcon or bald eagle populations would be of greater significance, neither of these species is known to have active nest sites within the CO_2 well field and impacts to populations of these species are also predicted to be minimal.

Loss of habitat would have a minimal, temporary adverse impact on most other birds that forage in those areas to be cleared of vegetation, since the disturbed area (2276 acres) would be less than 1 percent of the total CO_2 well field habitat. Early stages of revegetation may even benefit many species of small birds that feed on seeds as annual plants in the early successional stages produce abundant quantities of seeds.

Reptiles and Amphibians. Loss of some reptiles and amphibians during construction is expected to have a negligible impact on the populations of reptiles and amphibians in the vicinity of the CO_2 well field since the area disturbed represents only a small part of the total habitat.

None of the project facilities would be placed in the proposed rare lizard and snake area near the Utah border north of McElmo Creek. As human population and activity increase in the Four Corners area, more people may drive to the rare lizard and snake area, resulting in some amount of habitat deterioration and perhaps some captured animals. Problems of this nature as a result of the CO_2 project are expected to be minor and should have no significant impact on the reptile population in the proposed natural area.

Endangered and/or Threatened Fish and Wildlife.

Fish. Construction activity in the CO_2 well field would have no impact on endangered or threatened species of fish since no such species are known to be present in the streams of the area.

Wildlife. Three endangered species - the black-footed ferret, the bald eagle, and the peregrine falcon - may occur or have been observed in the vicinity of the CO_2 well field and are discussed below. No threatened species are known to occur in the CO_2 well field region.

The black-footed ferret is not known to exist at present in any part of Colorado, including the CO_2 well field; however, these animals are extremely secretive and historically have been sighted near Mancos southeast of the CO_2 well field, in southeastern Utah, and in northwestern New Mexico. Thus the possibility exists for the black-footed ferret to be present in the southern part of the field, especially along McElmo Creek where prairie dogs are present. The existing high level of land disturbance along McElmo Creek and the small amount of land to be disturbed in this area associated with five wells, one central facility, and related facilities greatly reduces the possibility that any black-footed ferret would be harmed by construction. In view of these factors, no impacts to the black-footed ferret are anticipated.

The peregrine falcon has been observed in the vicinity of the CO_2 well field but is not known to nest within the field itself. The closest known active peregrine falcon nest is 5 to 10 miles south of the CO_2

well field in the vicinity of Sleeping Ute Mountain. Construction activities in the field are expected to have no adverse impacts to the peregrine falcon prime habitat along Dolores Canyon since this habitat is presently unoccupied.

The bald eagle has also been observed in the vicinity of the CO_2 well field but is considered a winter visitor and is not known to nest in the well field vicinity. Thus construction activities are not expected to have an adverse impact on the bald eagle population.

Operation

Fish. Operation of the CO_2 well field is expected to have no impacts on fish populations or other aquatic organisms in the streams or other aquatic habitat in the vicinity of the field.

Wildlife. Operation of CO_2 well field facilities is expected to have no significant impact on wildlife species in the vicinity. Effects of operational noises and human activity (including increased use of off-road vehicles) are expected to be minimal and should not result in significant losses or displacement of wildlife.

Endangered and/or Threatened Fish and Wildlife. Operation of the well field facilities is not anticipated to have any impact on endangered or threatened species of fish or wildlife.

Summary

Construction and operation of the CO_2 well field facilities would temporarily remove 2276 acres of wildlife habitat and disrupt less than 1 mile of stream habitat. Disruptions to the streams would last only about 1 to 3 days during construction of pipelines and access roads across streams. About 2057 acres (90 percent) of the wildlife habitat removed during construction would be allowed to begin revegetation as construction activities are completed in each area. Temporary disturbance to less than 25 acres of crucial big game range should not cause a significant impact to big game species. The remaining 219 acres (10 percent) of the disturbed area would be occupied by buildings or access roads during the life of the project, after which time they would be allowed to revegetate. Some roads may be maintained permanently by the landowner or surface management agency and would not be revegetated.

Although some animals may be lost or displaced during project construction and operation, the number is expected to be less than 1 percent of the total population for any species in the CO_2 well field; thus impacts to wildlife populations are considered minimal.

It is not anticipated that project construction or operation would have an adverse impact on any endangered or threatened fish or wildlife species.

MAIN CO_2 PIPELINE

Construction

Fish. Construction of pipeline crossings at the Mancos, La Plata, Animas, San Juan, Rio Grande, and Pecos rivers is expected to have some effects on fish populations and other aquatic organisms in the immediate vicinity of the construction site and for a limited distance downstream. These effects may include the loss of a few fish during construction but generally consist of habitat deterioration resulting from increased sediment loads. Stream sedimentation is expected to increase for a few thousand feet downstream from the disturbance as a result of alteration of stream banks, removal of streamside vegetation, and disruption of the stream bottom during ditching. Such disturbances would be temporary since construction at the stream crossings would be completed in about 1 to 3 days. The amount of sediment at each crossing would be minimal since construction disturbance would affect less than 200 feet of the stream bank. In view of the minimal and temporary nature of the aquatic disturbances, construction of the pipelines across these rivers is expected to have no significant impact on fish populations in the river systems.

Wildlife. Removal of vegetation, rocks, fallen timber, etc. during the clearing operation would result in the loss of about 2980 acres of wildlife habitat. Construction of the pipeline and associated facilities is also expected to result in loss of some wildlife (primarily rodents, lizards, and the other small animals that tend to seek cover when alarmed rather than flee an area). Other animals such as deer, antelope, elk, raptors, game birds, and waterfowl are generally able to disperse to undisturbed areas during clearing operations, although a few of these animals may be destroyed in collisions with vehicles.

The wildlife species composition along the right-of-way and in other disturbed areas would change somewhat after the areas were cleared. The deer mouse, for example, is expected to increase in numbers in the disturbed area and replace many of the rodents present before the disturbance. As plant succession proceeded on the disturbed areas, the wildlife species composition in the disturbed areas would also begin to return to the predisturbance levels.

Effects to wildlife as a result of construction are expected to be minor and should have little significant impact on wildlife populations along the right-of-way or near the compressor station or microwave sites. These impacts are expected to be minor due to the small area of habitat to be disturbed (only about 4.7 square miles in the three states), the small amount of habitat to be disturbed at any one location, and the ability of many species to avoid construction areas during land clearing operations. The only crucial wildlife habitat to occur along the pipeline route is the crucial winter range for mule deer near the Continental Divide crossing in northwestern New Mexico. The amount of habitat lost due to a 50-ft clearing in this area is expected to be minimal in relation

to the total size of this critical habitat. Construction activity would be avoided in this area during the winter months when deer are present; thus effects of human activity on deer in this region should be minimal, with little significant impact on mule deer utilizing this principal wintering ground.

Endangered and/or Threatened Fish and Wildlife.

Fish. The Colorado River squawfish and the Pecos gambusia are the only fish species on the federal list of endangered and threatened species that could be affected by construction of the pipeline. No impacts to populations of these species are anticipated due to the minimal and temporary nature of the stream disturbances. In addition, the present range of the Colorado River squawfish does not include any of the rivers crossed by the pipeline. The Pecos gambusia should not be impacted since stream disturbances at the Pecos River crossing are not expected to extend downstream into the seven isolated locations within the Bitter Lakes National Refuge near Roswell, New Mexico where the species is present. Similarly, no significant impact is expected for populations of six species of fish listed as endangered by the state of New Mexico; these species include the humpback sucker in the Mancos and San Juan rivers, the roundtail chub in the Animas and San Juan rivers, and the bluntnose shiner, proserpine shiner, shovelnose sturgeon, and American eel in the Rio Grande.

Wildlife. The black-footed ferret, peregrine falcon, bald eagle, and whooping crane are the only endangered or threatened wildlife species that could be affected by construction of the pipeline system.

Pipeline construction is expected to have little effect on any black-footed ferrets, although prairie dog colonies (ferret habitat) may be present in the desert and plains grassland vegetation types along the right-of-way. The impact of construction on the black-footed ferret population is expected to be negligible since the habitat removed in any one location would be small and sightings of black-footed ferrets are rare in Colorado, New Mexico, and Texas.

Although peregrine falcons and bald eagles are occasionally observed in the pipeline region, pipeline construction is not expected to impact these bird populations significantly. Nest sites are not expected to be disturbed or destroyed since neither species is known to breed along the pipeline route. These birds are generally considered winter visitors to the pipeline region and may occasionally hunt for prey in the vicinity of the pipeline route. The number of prey animals that may be lost during pipeline construction (thus reducing a potential food source) is expected to be negligible due to the small area of habitat disturbed in any one location. Prey species (e.g., mourning dove, horned lark, cottontail rabbits) may actually increase in numbers along the pipeline right-of-way as weedy plant species, which provide a seed source, invade and increase in quantity on the disturbed areas during revegetation.

Whooping cranes would not be impacted since these birds nest in Idaho and are only winter visitors in the vicinity of the Rio Grande crossing. It is possible that some whooping cranes would be forced to leave the immediate vicinity during construction of the pipeline across the Rio Grande but this should have no impact on them.

Operation

Fish. Operation of the pipeline system would not affect aquatic habitat and would therefore have no impact on fish populations or other aquatic organisms in streams crossed by the pipeline.

Wildlife. Operation of the pipeline system is expected to have minimal impacts on wildlife populations along the affected route. Regular maintenance inspections of the pipeline would be conducted by aircraft and cathodic protection test leads placed near highway crossings so that an access road for inspection vehicles would not be needed along the right-of-way. Use of the right-of-way by off-road vehicles could increase the potential for wildlife harassment and cause a general decline in the quality of wildlife habitat near the right-of-way. These effects are not expected to be significant since much of the pipeline route passes through accessible areas (85 percent of the route is adjacent to existing rights-of-way). Fences across the right-of-way, especially on private lands, tend to discourage off-road vehicle use of rights-of-way.

Endangered and/or Threatened Fish and Wildlife. Operation of the pipeline system is expected to have no impact on endangered or threatened species.

Summary

Construction and operation of the pipeline system would cause the temporary loss of about 2980 acres of wildlife habitat and less than 1 mile of aquatic habitat. Revegetation would begin on over 99 percent (2957 acres) of the disturbed habitat following construction. Less than 1 percent (23 acres) of the disturbed area would be occupied by buildings or microwave structures throughout the life of the project.

Construction noises and some increased human activity along disturbed areas may cause some animals to move away from the disturbed sites. A few animals may be lost during clearing operations and in collisions with vehicles as a result of increased human activity in the area. These effects and losses would be minimal and are not expected to have a significant impact on any wildlife population.

Construction and operation of the pipeline system are expected to have only a minimal and temporary effect on aquatic habitat of rivers crossed by the pipeline. These effects should have no significant impacts on fish populations in these rivers.

No endangered or threatened species of fish or wildlife are expected to be impacted by construction or operation of the pipeline system.

OIL FIELD

Construction

Fish. No aquatic habitat is present in the oil field thus no impacts would occur to fish populations or other aquatic organisms.

Wildlife. Construction of the oil field facilities would result in removal of about 1295 acres of wildlife habitat. The grassland habitat to be removed is part of an area that has been widely disturbed by oil well facilities for many years. No critical habitat that could be affected is present. Some animals, such as cottontail rabbits, rodents, and small birds, would be lost during construction activities. Few game animals would be lost or displaced by construction since the density of such animals is generally already low in the oil field area. Impacts to wildlife as a result of construction of new oil field facilities, therefore, is expected to be minimal.

Endangered and/or Threatened Fish and Wildlife. No endangered or threatened fish or wildlife species are expected to be impacted by the oil field construction since none are known to exist in the vicinity of the oil field.

Operation

Fish. No aquatic habitat is present in the oil field thus no fish populations would be affected by operation of the oil field.

Wildlife. Operation of the oil field would result in minimal impacts to wildlife in the oil field. Operational noises and human activity could cause some animals to leave the area; however, these types of disturbances are already present in the oil field and any animals sensitive to these disturbances have most likely already moved from the area.

Endangered and/or Threatened Fish and Wildlife. Operation of the oil field facilities is not expected to impact any endangered or threatened species of fish or wildlife since none are known to occur in the vicinity of the oil field.

Summary

Construction and operation of the oil field facilities associated with the proposed project are not expected to have a significant impact on wildlife populations in the vicinity of the oil field. No fish populations are present in the area. The presence of low quality habitat

in the area as a result of existing oil field operations reduces the significance of the 1295 acres of wildlife habitat that would be removed during construction of facilities associated with the proposed project.

Construction and operation noises and relatively high human activity have been present in the vicinity of the oil field for many years so that impacts to wildlife populations as a result of any additional disturbances are predicted to be minor.

No endangered or threatened species of fish or wildlife are expected to be impacted by construction or operation of the proposed oil field facilities.

IMPACT CONCLUSION

Construction and operation of the proposed CO_2 well field facilities, the main CO_2 pipeline system, and the oil field facilities would cause some loss or disturbances to fish and wildlife but are not expected to have significant impacts on fish and wildlife populations in the region. Fish and wildlife losses would occur primarily during vegetation clearing operations in the construction phase. A few animals may also be lost in collisions with vehicles associated with increased population in the area during construction. Other animals may be temporarily displaced but would generally be able to become reestablished on disturbed areas as revegetation occurred.

An approximate total of 6551 acres of wildlife habitat would be removed as a result of the proposed project. Crucial wildlife habitat would be temporarily affected by construction of approximately 4 miles (less than 25 acres) of gathering lines in the CO_2 well field and a small portion of the main CO_2 pipeline near the Continental Divide in northwestern New Mexico. The loss of this crucial habitat is not expected to be significant to these big game species.

Impacts to fish and other aquatic organisms are not expected to be significant since disturbances to aquatic habitats at the pipeline and access road crossings would be small in area (generally a few thousand feet) and of short duration (1 to 3 days).

No significant impacts to endangered or threatened species are expected. Minor disturbances to two endangered species may occur during project construction: the endangered peregrine falcon and bald eagle would experience loss of hunting habitat and associated prey species but no known nest sites would be affected; the endangered Colorado River squawfish, Pecos gambusia, and whooping crane would not be impacted by the proposed project.

Impacts are not expected to occur to the black-footed ferret population (although some prairie dog colonies are present in the project vicinity) since these animals are rare and have not been observed recently in the project vicinity.

CULTURAL RESOURCES

From the project's inception, known cultural resources have been avoided in designing the proposed CO_2 facilities and rights-of-way. (An exception is the Goodknight-Loving cattle trail, which would be crossed by the proposed pipeline. Because the trail has not been used in many years, there is probably little physical remaining evidence.) After finalization of facility locations and rights-of-way and prior to construction (see Chapter 1, Authorizing Actions) a BLM Class III cultural resource survey would be undertaken to locate previously unknown cultural resources in the area to be disturbed. Any resources discovered during the survey would be avoided by the project if avoidance were prudent and feasible (as determined in consultation with the appropriate surface management agency). Previously unknown cultural resources not prudently or feasibly avoidable would be evaluated and data recovered as appropriate.

Construction

Presently known cultural resources have been avoided in project design, and would be avoided during construction. Resources located during the cultural resource survey would be avoided, recorded, or data recovered, so that only those unknown subsurface cultural resources encountered during construction would be directly impacted by project construction. Construction activities would alter, damage, or destroy unknown subsurface sites and result in disturbance to or loss of horizontal and vertical subsurface cultural information. Mixing loss of artifacts and stratigraphic data could also occur. Alteration, damage, or destruction of these resources could result specifically in the following:

- Loss of scientific and cultural information
- Loss of the physical expression of the resource
- Loss of the resource for future research
- Loss of the resources that may be valuable in terms of uniqueness
- Loss of resources that may have important cultural affiliations
- Loss of artifact material

An increase in the ease of access to two areas along the main CO_2 pipeline route not parallel to existing rights-of-way may result in indirect impacts to known cultural resources due to vandalism. In the first area, milepost (MP) 19 to MP 34, access would be provided to an area that is presently unaccessible by conventional vehicle. In the second area, MP 95 to MP 109, the pipeline right-of-way would increase the ease of access to an area criss-crossed by existing pipeline rights-of-way in the San Juan Oil and Gas Field. The creation and improvement

of access to these two areas would increase the potential for vandalism to cultural resources (destruction, alteration, or removal).

Deterioration of cultural resources, as well as alteration, damage, or destruction, could result from neglect. Neglect could occur if (1) increased federal agency management and protection, particularly patrolling, were not provided and (2) cultural resources on private lands are not maintained or protected by the landowner. In addition, an increase in area use could require an increase of federal agency management and protection, particularly patrolling, provided to the area.

Indirect beneficial impacts to cultural resources which could result from project construction are as follows:

- Cultural resources previously unknown could be located by the cultural resource survey and by monitoring construction to identify any subsurface sites uncovered during construction activities (especially trenching).

- Information previously unavailable could be recovered if significant sites are found during the cultural resource survey or during construction monitoring.

- Materials or artifacts previously unavailable could be recovered and made available to the public.

Operation

No direct impacts would occur to cultural resources from normal project operation. If emergency repairs were necessary and required clearing or trenching, adverse impacts could occur, as previously discussed for construction activities. The increase in ease of conventional vehicle access in conjunction with the decrease in project-related activity along these same routes once construction is completed would result in a greater potential for vandalism, as previously discussed, and therefore have an adverse indirect impact.

IMPACT CONCLUSION

Direct impacts in the CO_2 well field, along the main CO_2 pipeline, and in the oil field would be limited to construction (i.e., encountering subsurface sites not discovered during surveys). Sites encountered would be altered, damaged, or destroyed. Increased ease of access would be an indirect impact to the CO_2 well field and along the main CO_2 pipeline between MP 19 and MP 34, and MP 95 and MP 109. Increased resource knowledge through survey and analysis of previously unknown subsurface sites would have an indirect beneficial impact.

Because of the very high density of significant sites in the CO_2 well field it is possible that subsurface sites could go undetected and be destroyed during construction. Significant surface sites in the CO_2 well

field would be located during the archaeological survey and avoided during construction of well field facilities. In addition, identified sites preserved for future excavation could be vandalized due to improved public access into the area. However, if public access poses a problem, it may be controlled in the well-field area along with increased surveillance of the area to reduce the potential vandalism.

VISUAL RESOURCES

The Contrast Rating System within BLM's Visual Resource Management System (VRM) plus Visual Absorption Capability (VAC) information from the U.S. Forest Service (USFS) were used to determine the anticipated impacts of the proposed project on the visual resources. The VRM classifications identified in Chapter 2, Visual Resources contain management objectives to indicate the amount of visual impact (modification) that can occur within each class. A significant impact to visual resources occurs when a proposed action creates a modification contrast that will not meet the designated class objective. The severity of impact is determined by the class in which the feature is located. A more detailed explanation of this process is included in Appendix C.

All impacts to visual resources by the proposed CO_2 project would be caused by construction activities. No additional impacts from operation activities are anticipated.

CO_2 WELL FIELD

With the exception of dry-CO_2 gathering lines, visual resource impacts to the CO_2 well field are assessed on a typical worst-case basis for each project element that have an impact. Impact evaluation takes into consideration revegetation stipulations discussed in Chapter 1, Proposed Action as well as natural revegetation.

Construction

Dry-CO_2 Gathering Lines. Construction of the dry-CO_2 gathering line between the eastern and western rims of Dolores Canyon would disturb the surface and remove existing vegetation. The resulting contrast would not meet VRM Class II objectives. Revegetation efforts after construction would take 5 to 15 years to reestablish vegetation to sufficient heights to reduce the impact and meet VRM Class II objectives. From the eastern rim of the canyon to the forest service road vegetation removal would cause a contrast that exceeds VRM Class IV objectives. Revegetation after construction would take 1 to 2 years to establish enough cover to meet VRM Class IV objectives.

A dry-CO_2 gathering line enters McElmo Creek Valley on the eastern and western ends via a canyon wall. Disturbance to the landform and vegetation removal would cause a visual contrast that would exceed VRM Class III objectives. Where gathering lines cross dense pinyon juniper vegetation the resulting contrast would exceed VRM Class IV objectives for an estimated 5 to 15 years until woody vegetation became reestablished.

Removal of vegetation for the construction of a gathering line near Narraguinnep Reservoir west of Dolores would create a contrast that would exceed VRM Class III objectives.

Wet-CO_2 Gathering Lines. Pipeline construction that does not occur within or adjacent to access road rights-of-way would have significant impact to the visual resource in the following situations where the route:

- does not blend with existing contours
- intersects an observation point at right angles and where vegetation is moderately dense
- occurs on a highly visible slope with little or no vegetation
- crosses areas with dense vegetation

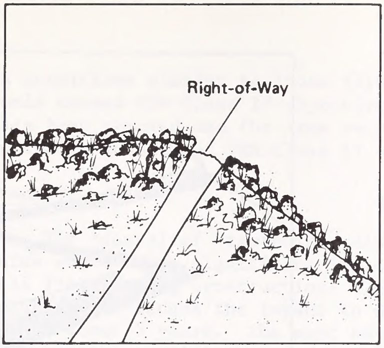
Figure 3-2 illustrates some of these situations. These conditions would generally create contrasts that would exceed VRM Class IV objectives.

Access Roads. Construction of new access roads would have significant impact to visual resources as a result of vegetation removal and/or alteration of the landform. Figure 3-3 illustrates some of the conditions that would create the greatest contrasts, especially in areas with few intrusions. All of these conditions would exceed the management objectives of VRM Class IV.

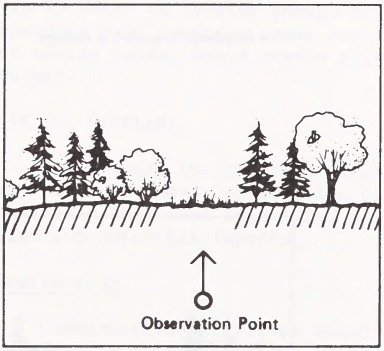
Transmission Lines. The construction and presence of transmission lines would have a significant impact on visual resources, (1) in areas with few cultural modifications, (2) where canyons are crossed, (3) where dense vegetation is found, and (4) when the alignment does not take into consideration the existing cultural modification or natural landform patterns. One or more of the above conditions combined would create contrasts that would exceed VRM Class IV objectives.

Central Facilities. The construction of a central facility would remove about 5 acres of vegetation and introduce atypical structures in an agricultural landscape. Contrasts would exceed the allowable limits for VRM Class IV when the facility is located on flat terrain with little background landscape or vegetation. Significant impacts would also occur when the facility is located in the foreground or in dense vegetation.

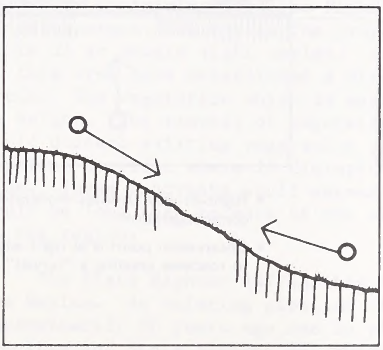
Drill Rigs. The removal of vegetation, alteration of landform, and introduction of structures (see Figures 1-1, 1-2) would create significant impacts to visual resources during construction. During construction



- Right-of-way does not follow natural lines of the landscape

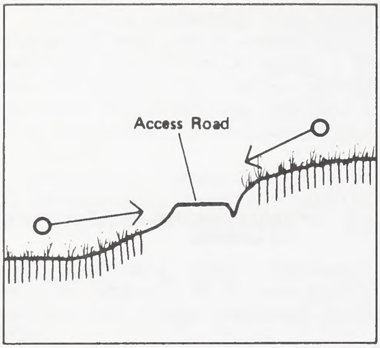


- Right-of-way removes moderately dense vegetation
- Observation point is at right angle to right-of-way (tunnel view)

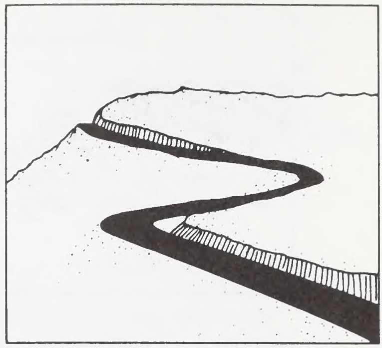


- Hillside has slope greater than 25%
- Hillside has little or no vegetation
- Right-of-way or viewer is elevated

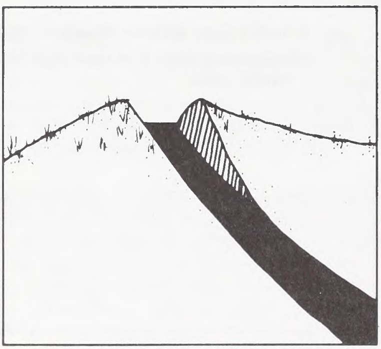
Figure 3-2. WORST-CASE CONDITIONS FOR WET-CO_2 GATHERING LINES



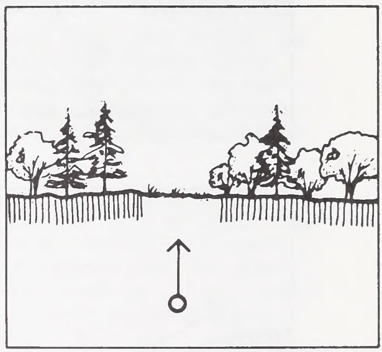
- Roadway requires cut and fill
- Area has little vegetation
- Right-of-way or viewer is elevated



- Roadway traverses a hillside



- Roadway requires cut and fill and does not follow natural contours



- Right-of-way removes moderately dense vegetation
- Observation point is at right angle to roadway creating a "tunnel" view

Figure 3-3. WORST-CASE CONDITIONS FOR ACCESS ROADS

in conditions similar to those illustrated in Figure 3-4, contrasts would exceed VRM Class IV objectives. After the drill rig and trailers have been removed and the area recontoured and revegetated, the reduced contrasts would meet VRM Class IV objectives.

Summary

The removal of vegetation, disturbance of soil, or addition of structures would cause significant impacts to visual resources in the CO_2 well field during construction. In most cases (VRM Class IV), revegetation would reduce the impact to meet acceptable VRM class objectives within about 5 years. The most severe impacts would be associated with construction on hillsides and canyon walls such as Dolores Canyon or in areas of high sensitivity (visibility). These areas would require 5 to 15 years to develop enough vegetative cover to reduce the impact. Depending upon location, some project elements such as central facilities and access roads, would create significant impact for the life of the project.

MAIN CO_2 PIPELINE

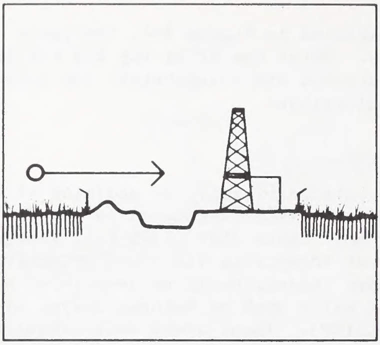
Areas where the proposed pipeline project elements would be visible from major roadways, observation points, communities, or recreation facilities have been identified as viewsheds. Each viewshed is evaluated below for potential impacts.

Construction

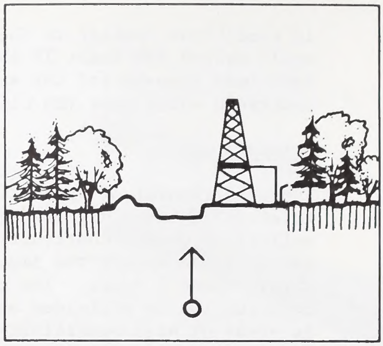
Construction activities would have significant impacts on visual resources in eight viewsheds (Table 3-10).

Viewsheds Containing Pipeline Right-of-Way. Approximately 15 miles north of Albuquerque, New Mexico the proposed pipeline would intersect Interstate 25 at nearly right angles. Several natural and cultural elements in this area have established a strong linear effect which flows north and south. The vegetation which is mixed sagebrush and juniper trees varies in height. The removal of vegetation in a 50-ft width of the right-of-way would disturb existing vegetation patterns and draw attention to the pipeline corridor where it disrupts and contrasts the existing linear flow. These contrasts would exceed VRM Class II objectives. The impact would be long term because of the slow natural regrowth of vegetation in the region.

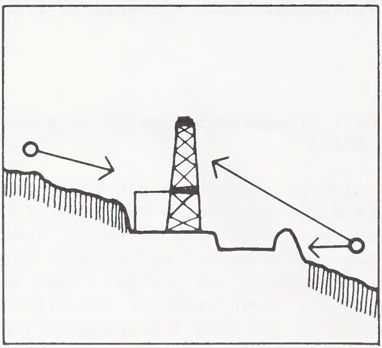
The State Highway 44/Placitas viewshed is located north of Albuquerque, New Mexico. An existing pipeline right-of-way was cleared at this site approximately 20 years ago and is plainly visible from the small town of Placitas and State Highway 44, which experiences local recreational travel



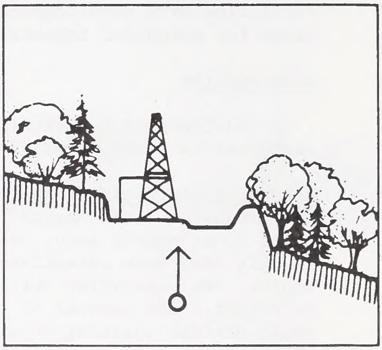
- Facility is located on flat non-cropland terrain with sparse, low vegetation



- Moderately dense vegetation is removed
- Area is highly visable



- Facility is constructed on moderate to steep slopes (greater than 20%) with sparse, low vegetation



- Moderately dense vegetation is removed
- Area is highly visable

Figure 3-4. WORST-CASE CONDITIONS FOR DRILL RIGS DURING CONSTRUCTION PHASE

Table 3-10. IMPACT SUMMARY FOR VISUAL RESOURCES ASSOCIATED WITH MAIN CO_2 PIPELINE

Action	Feature Causing Impact*	Feature Score	VRM** Class
Pipeline construction at Viewshed I-25	vegetation - long-term	13	II
Pipeline construction at Placitas/State 44 Viewshed	vegetation - long-term	23	II
Pipeline construction at State 14 Viewshed	vegetation - long-term	23	-
Pipeline construction at Duran/U.S. 54 Viewshed	vegetation - long-term	19	III
Compressor station construction at Torreon	structure - long-term	23	IV
Transmission line construction at Torreon	structure - long-term	26	III & IV
Microwave construction at Ramon Viewshed	structure - long-term	27	IV
Microwave construction at Duran Viewshed	structure - long-term vegetation - long-term	23 17	III III

*Significant impacts are determined by the degree of contrast the proposed action would have on any one of three features of the landscape (landform, vegetation, structure). See Appendix C for explanation of methodology.

**Maximum feature scores for VRM classes are as follows:

Class I = 10
Class II = 12
Class III = 16
Class IV = 20

(Figure 3-5). The construction of the proposed pipeline would remove an additional 50 feet of fairly dense juniper trees south of and adjacent to the existing right-of-way. This action would create strong cumulative contrasts in form and line that would be long term (40 years) due to slow natural regrowth.

State Highway 14, which would be intersected by the pipeline northeast of Albuquerque, is considered a local scenic highway where it passes through the eastern slopes and foothills of the Sandia Mountains. The composition of vegetation and terrain is similar to that of Placitas and similar cumulative contrasts would be caused by the removal of vegetation adjacent to an existing right-of-way.

From the viewshed at the intersection with U.S. Highway 54, the major visual relief provided is Duran Mesa and the nearby juniper-covered rolling hills. The proposed pipeline would intersect the highway at right angles and remove a 50-ft wide band of vegetation; a "tunnel" effect would be created and existing vegetation or terrain patterns disrupted (Figure 3-6). The resulting contrast would be most noticeable where the roadway is lower in elevation than the corridor, thereby increasing the viewing angle. This impact is expected to be long term.

Viewsheds With Above Ground Facilities. The compressor station and portions of the transmission line would be visible from State Highway 197 near Torreon, New Mexico. The visual contrast resulting from the facilities in an area with few cultural modifications would affect the basic elements of form, line, color, and texture. This localized impact is expected to remain for the life of the project. Little vegetation would be removed during construction of the transmission line, but its presence represents a strong contrast in form and line to the surrounding landscape. The 115-kV line, which would have double support poles, would be 6 miles in length and would follow a straight alignment. The presence of the transmission line would create uncharacteristic rigid lines, but the contrast would diminish somewhat as the distance between the viewer and the line increased.

Communications towers constructed in areas of relatively flat terrain, such as the viewshed near Ramon on U.S. Highway 285, can be expected to be up to 160 feet in height. This tower's configuration and color, isolation from other similar cultural modifications, and location adjacent to a regularly traveled road would create a significant contrast in line and form that would be visible for miles (Figure 3-7). Appendix F (Maps F-2 through F-11) shows the location of communications towers.

The communications tower located on Duran Mesa would be visible from both Duran and U.S. Highway 54. The mesa is a highly visible feature in an otherwise flat area and is easily drawn into the line of sight. Although the tower would be only 70 feet in height, it would disrupt the horizontal line of the mesa top and attract attention. This contrast would exceed VRM Class IV objectives for the life of the project.

Figure 3-5. EXISTING PIPELINE RIGHT-OF-WAY IN THE PLACITAS VIEWSHED

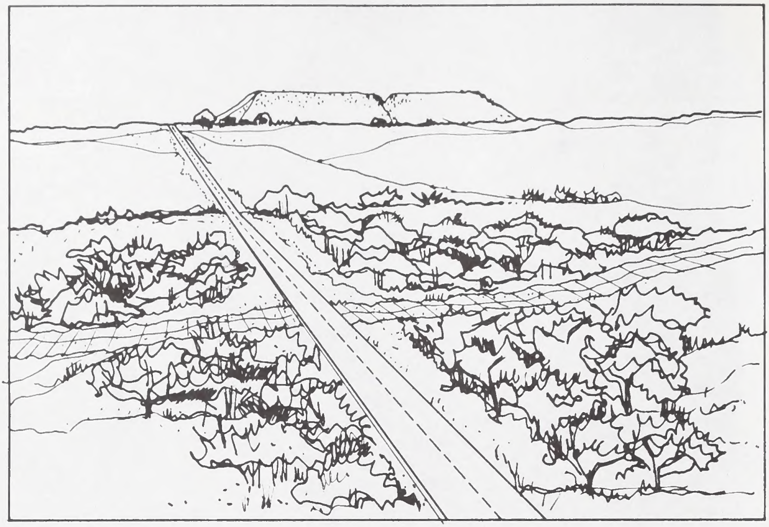


Figure 3-6. GENERALIZED VIEW OF PIPELINE CROSSING U.S. HIGHWAY 54 NEAR DURAN

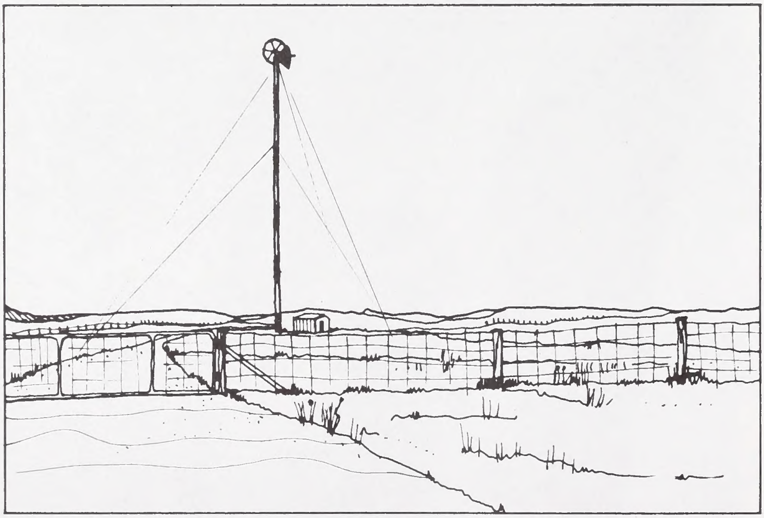


Figure 3-7. GENERALIZED VIEW OF COMMUNICATIONS TOWER NEAR RAMON ON U.S. HIGHWAY 285

Summary

The actions associated with the construction of the pipeline system are expected to create contrasts in all VRM classes identified in Chapter 2, Visual Resources. The most significant impacts of pipeline construction would occur where the pipeline intersects four roadways. Microwave construction activities are expected to have significant impacts in two viewshed areas in New Mexico. The physical presence of the compressor station and transmission line would also have significant impact on visual resources. All of the impacts would remain in effect during the 30-year life of the project.

OIL FIELD

There would be no visual resource impacts during construction of project facilities in the oil field.

IMPACT CONCLUSION

Project implementation would result in both short and long term visual resource impacts. Canyon lands and naturally vegetated areas in the CO_2 well field would be more susceptible to visual impacts than the flatter mesa tops and agricultural lands. Longer periods of time would be required to reduce impacts on canyon walls. The pipeline crossing in Dolores Canyon would take 5 to 15 years to establish enough cover to reduce the impact and meet the VRM Class objective. Most construction, however, would take place on the mesa tops and in agricultural lands where contrasts would be less severe and require less time (1 to 2 years) to establish enough cover to reduce the impacts. Some areas, such as on steep slopes, or on shallow soils, may never recover sufficiently to reduce impacts where revegetation success is expected to be poor.

Along the main CO_2 pipeline construction activities would be highly visible in 25 different locations (viewsheds). Visual resource impacts would be significant and long term in eight viewsheds.

No visual resource impacts would occur in the oil field.

RECREATIONAL RESOURCES

CO_2 WELL FIELD

The 320,000 acres of the proposed CO_2 well field are mostly undeveloped public lands controlled by the BLM and the U.S. Forest Ser-

vice (USFS). The remaining portions are primarily privately owned and used for farming. State Highway 666 runs between the two sections of the CO_2 well field, McElmo Dome and Doe Canyon fields. From this highway there is access to all mesas and many of the major canyons in the area via a network of improved and unimproved roads. Many of the existing roads in the McElmo Dome Field provide access to the numerous agricultural fields in the area.

The new access roads required by the proposed project would increase access in to the CO_2 well field, though the potential increase would be minimized by the use of existing roads for approximately 120 of 159 miles of access roads required.

Construction

Developed Recreational Opportunities. Three developed recreational areas are located within the CO_2 well field: Hovenweep National Monument, Lowry Ruins, and Sand Canyon. Each area is accessible by existing improved roads. Precise figures on the number of visitor days at each of these areas are unavailable, but increased usage by construction crews and their families in Cortez is expected to be negligible. Population increase due to the proposed CO_2 project would be less than 9 percent at the peak of construction. Assuming 2 visits per person to each each of the recreational areas annually, about 1000 more visitor days per area per year would result, or less than 3 additional people per day. This is an average rate of usage and would vary by season. An existing improved road system leads to each of these areas, thus no major changes are expected in use by current local residents or by outside visitors.

Undeveloped Recreational Opportunities. The public lands in the CO_2 well field are open to the public for any activity except building fires and digging holes. Current principal activities in the area include hunting, fishing, picnicking, hiking, and some off-road vehicle (ORV) recreation. The project would do little to alter these activities except to diminish the aesthetic appearance of the mesas where the well pads would be located. The canyon would be unaffected except for a few access roads or gathering lines.

Construction activities in the CO_2 well field may cause some game species, especially mule deer, to temporarily avoid open areas near construction sites. This displacement should not have a significant impact on hunting since undisturbed cover would still be available in the CO_2 well field and the actual number of game animals displaced would be small. The number of new licensed hunters in the region as a result of project-related population increases is expected to be no more than 50 (based on an 8:100 ratio of big game hunters to total population and a predicted maximum population increase of 680 people). This represents only about a 1 percent increase in the number of licensed mule deer hunters in Montezuma and Dolores counties and would have negligible impact on the hunting success of big game hunters.

Construction of access roads and/or gathering lines across the Dolores River and McElmo Creek is not expected to impact fishing opportunities. Disturbances due to construction activities would last no more than 3 days at any one location and would extend a few thousand feet downstream of the crossing.

The aesthetic pleasures of river rafters would be diminished during construction. This impact would be negligible, however, due to the limited period of construction at each crossing. In addition, construction at river crossings would occur at times of relatively low water levels when the river usage for rafting is low.

The presence of heavy equipment during construction would make the area less desireable for picnicking and hiking. However, the areas most affected by construction activities would be the mesas, many of which are now agricultural land. Assuming that the canyons are the heavily used recreation areas, construction activities would have little effect on recreation except to disturb the user's aesthetic pleasures from the nearby mesa areas. Given the vast amount of area available for hiking and picnicking, activities should not be significantly disrupted by construction activities. Further, large increases in use by visitors from outside the local areas are not expected to result from accessibility improvements as sufficient access already exists for those interested.

Operation

Developed Recreational Opportunities. Operation of the pipeline would require a year-round staff of 40 persons, many of whom would live with their families in Cortez. The increase of approximately 110 permanent residents would have no measurable effect on the recreational opportunities at Hovenweep National Monument, Lowry Ruins, or Sand Canyon.

Undeveloped Recreational Opportunities. Operation of the CO_2 well field is not expected to reduce the number of game animals in the area, thus there would be no decrease in hunting opportunities or expected harvest success. The presence of and activity associated with the 40 operational personnel may cause some big game species to avoid the immediate area of the well facilities and central facilities. Displaced animals would probably seek cover in the numerous canyons and mesa slopes rather than leave the CO_2 well field. Operation would have no effect on local fishing or boating activities in the Dolores River or McElmo Creek. Hiking and picnicking would be unaffected except for diminished aesthetic appeal due to the presence of the CO_2 wells and other surface structures; because wells are widely spaced and not generally visible from other well sites, the aesthetic effects should be small.

Summary

Recreational opportunities would change little due to construction and subsequent operation of the CO_2 well field. The principal impact, both in the short term and the long term, would be diminished aesthetic appeal in the areas of disturbance. This effect should be small as the well facilities are widely spaced and not usually visible from other well sites.

MAIN CO_2 PIPELINE

Construction

Developed Recreational Opportunities. Cibola National Forest is located within the area of the proposed pipeline; Bitter Lakes Wildlife Refuge is located nearby. Pipeline construction crews and their families are expected to live in Cortez, Farmington, Albuquerque, and the Hobbs/Roswell area. Most of them would come from the existing population, resulting in only a small number of new residents (less than 100) to any of these cities. The presence and impact of these newcomers on recreational opportunities enjoyed by current users of Cibola National Forest would be insignificant. Similarly, improvement in the road system would be so small that it should not affect usage by visitors from outside the local area. The principal impact for all users would be possible increased inconvenience in traveling to Cibola National Forest due to temporary use of major highway and access roads by construction equipment. This effect is short term and so small that it should deter no one from using the forest.

Undeveloped Recreational Opportunities. Construction of the pipeline may increase ease of access and thus encourage use by hunters, but only in those areas where the proposed pipeline deviates from an existing right-of-way. An increase in the number of hunters in any one region is expected to be small and to have an insignificant impact on the area's hunting resource.

Construction of the pipeline across the La Plata, Animas, San Juan, Rio Grande, and Pecos rivers is expected to have no impact on fishing activities in affected streams. The time period of stream disturbance is expected to be short and the area of disturbance should extend only a small distance downstream.

Other recreational activities, such as hiking and picnicking, would be disturbed only briefly. The pipeline crews would move at a rate of several miles per day, and their activities would not restrict access to environmentally unique areas. Hikers and picnickers could easily go to similar nearby areas to avoid noise and dust from construction activities. Again, the most significant impact on recreational access would be due to increased use of roads in the local area, but this is not expected to reach a level that would prohibit desired recreation.

Operation. Operation of the pipeline would have no impacts on use of developed recreational opportunities or access to other casual recreation activities such as hunting, fishing, hiking, or picnicking. The project would not measurably affect access to the public lands and should result in only a minimal increased usage of the pipeline area by ORV recreationists. The potential impact of those persons new to the area is too small to measure.

Summary

The area disturbed by the pipeline is less than one-half of the total acreage devoted to the pipeline right-of-way. In addition, the pipeline route parallels an existing line for the majority of the proposed route. Impacts attributable to the proposed pipeline would occur during construction. These would be short term and would result in no significant changes to recreational opportunities.

IMPACT CONCLUSION

The lands most affected by the proposed project are those devoted to the CO_2 well field. The principal impact, mainly affecting hikers and picnickers, would be diminished aesthetic appeal due to the presence of surface disturbances and facilities. Impacts to recreational opportunities along the pipeline route are considered negligible.

AGRICULTURAL RESOURCES

Agricultural resources consisting of farmland, livestock grazing land, and forest land would be affected by construction and operation of the proposed project in the CO_2 well field, and along the main CO_2 pipeline.

CO_2 WELL FIELD

Construction

Farmland. Construction of access roads, well facilities, and gathering lines would disrupt approximately 150 irrigated acres and 868 non-irrigated acres of cropland. The total of 1018 acres to be disturbed represents about 1.5 percent of the total number of acres of cropland presently under cultivation in the CO_2 well field.

This disruption should not cause any significant hardships to farming operations since construction would disrupt only a few acres in any one area. Approximately 945 acres (primarily associated with gathering lines) could be returned to productivity within a year

after construction completion. The remaining 73 acres would be occupied by new access roads and buildings for the 30-year life of the project. These losses of cropland would have a negligible impact on the total crop production for the CO_2 well field and vicinity.

Livestock Grazing. Loss of vegetation on approximately 1255 acres of grazing land (excluding riparian and agricultural vegetation) would reduce the amount of livestock forage in the CO_2 well field. The annual loss of forage would be at a maximum (100 animal unit months [AUMs]) immediately after the vegetation is cleared from construction sites. Grazing capacities would then increase as vegetation becomes reestablished on disturbed areas other than access roads and building sites (which would be excluded from grazing completely for 30 years). The total reduction in livestock grazing capacity as a result of construction in the CO_2 well field is estimated at 1090 AUMs for the life of the project (Table 3-11). A loss of 100 AUMs or less per year represents approximately 0.5 percent reduction in annual AUMs for the CO_2 well field. The impact of this small decrease would be negligible to livestock grazing in the CO_2 well field.

Forestry. Construction of access roads, gathering lines, and well facilities in the higher elevations of the CO_2 well field northeast of the Dolores River would result in the clearing of 139 acres of ponderosa pine forest. This acreage would be precluded from reestablishment of commercial timber for the 30-year life of the project and should not alter current timber management practices in the CO_2 well field.

Operation

Operation of the CO_2 well field would not require clearing any additional croplands, rangelands, or forests; thus, operation would not result in any additional impacts to crop production, AUMs, or timber production.

Summary

Construction and operation of the CO_2 well field would disturb 1018 acres of farmland, 73 acres of which would remain out of production for the 30-year life of the project. Removal of vegetation would result in the loss of an estimated 1090 AUMs in the CO_2 well field during the project life of the project. Approximately 139 acres of potential timber land would be removed from production during the life of the CO_2 well field. All of these losses are small and would have a negligible impact on the farming, grazing, and timber resources of the CO_2 well field.

Table 3-11. ESTIMATED REDUCTION IN ANIMAL UNIT MONTHS (AUMs)

Grazing Area*	Acres Disturbed	AUM Reduction First Year	Total AUM Reduction
CO_2 Well Field	1255	100	1090
Main CO_2 Pipeline	2776	380	2920
Total	4031	480	4010

*Excludes riparian and agricultural areas.

MAIN CO_2 PIPELINE

Construction

Farmland. Pipeline construction would result in the temporary disturbance of about 194 acres of agricultural lands. Crop production would be lost on this acreage for one growing season, since no permanent above ground facilities would be located on agricultural lands. This temporary loss of production would be dispersed over about 32 miles of the pipeline right-of-way and would have a negligible impact on the crop production of any one area.

Livestock grazing. Clearing of vegetation on approximately 2776 acres of grazing lands would temporarily reduce the grazing capacity by an estimated 2920 AUMs (Table 3-11). The maximum annual reduction in AUMs (380) would occur during the first year immediately after construction and would decrease thereafter as vegetation became reestablished on the disturbed areas. A maximum annual loss of 380 AUMs along a 478-mile right-of-way (50-ft clearing) averages to less than 1 AUM per mile. Losses of this size are negligible and would not hinder or otherwise impact any ranching operations or grazing allotments.

Forestry. Construction of the main CO_2 pipeline system would not affect any commercial forest resources along the proposed pipeline route.

Operation. Operation of the main CO_2 pipeline system would not require clearing any additional croplands, rangelands, or forests; therefore, operation would not result in any additional impacts to crop production, AUMs, or timber production.

IMPACT CONCLUSION

Construction and operation of the proposed project would result in the loss of 1134 acres of crop production for 1 year and 78 acres for 30 years for a total of 1212 acres of affected agricultural land, 4010 AUMs during the life of the project, and 139 acres of potential commercial forest lands. These losses are small and would have a negligible impact on the agricultural resources of the project region.

WILDERNESS VALUES

Section 603 of The Federal Land Policy and Management Act of 1976 (PL 94-575), Bureau of Land Management Wilderness Study requires that parcels of public land of 5000 acres or more and roadless islands within

public land (identified during the inventory required by Section 201[a] of the Act as having wilderness characteristics described in the Wilderness Act of September 3, 1964) be reviewed in light of their potential designation as Wilderness Study Areas. Lands within the CO_2 well field and along the main CO_2 pipeline route are in various stages of wilderness review.

CO_2 WELL FIELD

Construction

In the Doe Canyon portion of the well field, the San Juan National Forest lands contain no areas suitable for wilderness study under U.S. Forest Service (USFS) procedures (RARE II). The McElmo Dome Field, although not yet subjected to formal screening procedures, may have roadless areas suitable for wilderness review. These areas are Yellowjacket, Woods, Sandstone, Ruin, and Cross canyons, and McLean Basin. The areas considered in each reach from rimrock to rimrock across the canyon floors. Based upon this potential the idealized CO_2 well field layout (Appendix F, Map F-1) avoids these areas where conditions permit. The exceptions to this are three potential wells in Woods Canyon and about 3 miles of access road and wet-CO_2 gathering line right-of-way, and an electric transmission line crossing of Yellowjacket Canyon.

The impact of proposed facilities on potential roadless and wilderness study areas would be minor. The described areas have not been subjected to formal screening procedures; the potential areas were located intuitively. In addition, Chapter 4, Guidelines for Specific Activities, Section 3 (a),(b),(c),(d), and Appendix B-1 of the Bureau of Land Management Draft Interim Management Policy and Guidelines for Wilderness Study Areas set forth procedures controlling mineral leasing and exploitation on public lands (under NTL-6). Such activities are neither exclusively prohibited nor encouraged. Appendix A of the same document provides guidance for activities not covered by NTL-6, i.e., the proposed electric transmission line crossing of Yellowjacket Canyon.

Operation

There will be no additional impacts due to operation.

Summary

The impact of proposed facilities on potential roadless and wilderness study areas in the CO_2 well field would be minor.

MAIN CO_2 PIPELINE

Construction

In New Mexico the main CO_2 pipeline would traverse portions of and pass parallel to seven potential Wilderness Study Areas. The proposed pipeline would traverse about 19.4 miles (235 acres of 100-ft right-of-way) of potential Wilderness Study Areas. In all cases, the proposed rights-of-way have been reviewed and determined by BLM not to meet the criteria for wilderness.

The proposed right-of-way in these areas is adjacent and parallel to existing rights-of-way. Pipeline construction would, therefore, not have any impact on wilderness values along the proposed route.

Operation

There will be no additional impacts due to operation.

Summary

The impact of the proposed main CO_2 pipeline on potential roadless and wilderness study areas would be minor.

IMPACT CONCLUSION

While some minor impact (the presence of facilities) on potential Wilderness Study Areas would result from project implementation, no major impacts on potential or future designated Wilderness Study Areas is expected to occur.

MINERAL RESOURCES

CO_2 WELL FIELD

The impact of the proposed facilities in the CO_2 well field on current or future production of mineral resources (other than CO_2) would be negligible due to the small amount of land required for development. The proposed project would remove CO_2 from the well field at the rate of approximately 400 million cubic feet per day for the 30-year life of the project, but would not preempt the exploration of other natural resources.

MAIN CO_2 PIPELINE

An area of commercially strippable coal underlies the proposed route of the main CO_2 pipeline in northwestern New Mexico. The proposed right-of-way would not interfere with any existing or proposed coal mining operation.

In the event that strip mining were proposed for the coal under the right-of-way at a later time, the pipeline would be moved. Movement of the pipeline would be an issue discussed in the environmental assessment for the proposed coal mining operation.

TRANSPORTATION NETWORK

CO_2 WELL FIELD

Construction

The proposed action would cause short-term increases in large trucks hauling materials and equipment and commuter travel during construction and long-term increases in ease of recreation travel during operation. Employees commuting from Cortez to construction sites would temporarily increase traffic on primary roads including U.S. Highway 666, Pleasant View Road, and McElmo Creek Road and on county roads within the CO_2 well field. Greater use of these roads would cause some increased congestion, maintenance, vehicle accidents, and noise levels.

Operation

There would be no impact on existing or project improved transportation networks during operation of the CO_2 well field. Impacts from the proposed development of 39 miles of new access roads to connect existing routes and construction locations that are presently semi-isolated are discussed in Chapter 3, Recreational Resources.

Summary

Impacts to the transportation network of the CO_2 well field are limited to construction; however, ease of access would be increased during the life of the project.

MAIN CO_2 PIPELINE

Construction

Movement of materials, equipment, and commuter vehicles during construction of the proposed pipeline would create a short-term increase in traffic and a potential for highway accidents in the vicinity of the rights-of-way. Access to work sites along the pipeline corridor would require the use of primary and secondary roads. Because the commuting work force would be dispersed in several communities in temporary quarters and may relocate a number of times, specific impacts on these roads are difficult to estimate but are thought to be minor. Due to the small number of workers involved at one location at any given time and the short overall duration of the construction period, the magnitude of this increase would be small.

Operation

Minor impacts during operation would be associated with use of the rights-of-way for recreation activities (see Chapter 3, Recreational Resources).

Summary

There would be no impacts to existing transportation networks during operation of the main CO_2 pipeline.

IMPACT CONCLUSION

The impact of project related traffic to existing transportation networks would be minor and limited to the construction period. Impacts on increased ease of access in the CO_2 well field are discussed in Chapter 3, Recreational Resources.

SOCIOECONOMICS

Analyses of changes in local population and subsequent socioeconomic impacts have been based on estimates of three potential new population components: (1) the number of project-related new-to-the-area employees, (2) the number of new-to-the-area home bases, and (3) the number of new-to-the-area employees who would fill jobs created by new demand for secondary services. In the absence of appropriate models to provide such estimates, the systematic approach outlined below was used. Professional judgment and the experiences of other local areas with new industrial projects were applied.

The first basis used to estimate local population changes is the approximate number of jobs required to accomplish project construction and operation; second is the estimate of how many of those jobs would be filled by persons who do not now reside within the local area.

Once the number of new-to-the-area employees is predicted, estimates must be made for how many of those employees would bring spouses and how many would bring larger family groups. Two factors are considered when making this estimate: the length of time the new employee would work in the area and the distance from home base to the new project. The assumptions underlying these considerations are:

- The shorter the period of employment, the less likely the employee is to move other persons from home base
- The shorter the distance from home base to the new job, the less likely the new employee is to move other persons from home base. This second assumption is based on the experience of other projects (such as the Jim Bridger Power Plant) that have indicated that workers may travel up to 100 miles one way daily.

The final bases required to predict change in local population characteristics are (1) an estimate of the number of new jobs created in the area's services and retail employment sectors and (2) of those jobs, the number that would be filled by persons who do not now reside in the local area. New local employment in secondary services is primarily contingent on the nature of the local population changes. New demand for services which cannot be met by existing secondary service businesses is estimated based on the proportion of new income that will be spent in the local area. It is assumed that the greater the number of new home bases, the higher the new demand for secondary services. In addition, new demand for services must be of sufficient duration to warrant opening of new businesses. If new businesses are not established, then existing businesses are not as likely to require employees who are new to the area.

CO_2 WELL FIELD

Construction

The construction of the well facilities, central facilities, wet-CO_2 gathering lines, and dry-CO_2 gathering lines would require a construction work force of 245 to 470 people during the peak construction period (1980 to 1983) (Chapter 3, Table 3-2). This work force would be drawn from three geographic regions: local, or areas within daily commute distance (primarily Cortez); semi-local, or areas within weekly commute distances (primarily Moab, Utah about 150 miles from Cortez and the Aztec-Bloomfield-Farmington area in New Mexico

about 70 miles away); and outside the region, or areas such as Albuquerque, Denver, and cities in Oklahoma and Texas, where people with special construction skills are located. Construction of the dry-CO_2 gathering lines would require the highest proportion of specialized labor in the project.

Approximately 33 percent of the construction work force is expected to be met by the local labor supply (Table 3-12). About 50 percent of the work force is estimated to originate in semi-local areas while about 18 percent would originate outside the region. Thus approximately 175, 260, and 95 workers from the local area, semi-local area, and outside the region, respectively would be needed to meet the construction work force requirements for the peak construction period (Table 3-12).

These work force requirements would alter the population of the area and may affect socioeconomic conditions, including housing, public facilities and services, income and expenditures, taxes, and human expectations and lifestyles.

Population. Population in the Cortez area is expected to increase as a result of the number of semi-local and outside employees who would move to the area. An assumed 15 percent of these employees would form one-person households. Data from previous construction projects indicate 50 to 75 percent of employees from outside the region bring their familes with them and that average family size ranges from 3.5 to 3.9 persons (HUD 1976). The estimate of the number of persons in new home bases* is dependent on the following worst-case assumptions:

- For the 20 operations employees, 85 percent would move home bases to Cortez with an average family size of 3.9.

- For the semi-local employees (Farmington/Moab), 25 percent would move home bases to Cortez with an average family size of 2. This multiplier assumes that semi-local employees with children of school age would not move home base due to the short duration of the construction project.

- For employees from outside the region, it is assumed that 75 percent would bring families of 3.9 members and 25 percent would be unaccompanied.

Based on these assumptions, the estimated total number of new people in the Cortez area would be 680 at the time of peak employment in 1982 (Table 3-13). The analysis assumes the total influx would be located in Cortez (although the demands for services would probably be more geographically dispersed). If all new personnel, including weekly commuters,

*Home base refers to a quasi-permanent (for this project, 1 to 3 years) household established by new-to-the-area employees.

Table 3-12. PERCENT AND NUMBER* OF EMPLOYEES BY CONSTRUCTION TASK, GEOGRAPHIC ORIGIN, AND YEAR

			Year												
	Origin	%	79	80	81	82	83	84	85	86	87	88	89	90	2000
Well site Prep.	L	40	6	50	50	35	30	15	15	5	5	5	5	5	?
and Drilling	S	60	9	70	70	55	40	20	20						?
	O														?
Central	L	40			35	55	35								?
Facilities	S	60			55	85	55								?
	O														?
Wet-CO_2	L	40		10	20	55	35	10	10	5	5	5	5	5	?
Gathering	S	50		25	50	70	40	10	10						?
Lines	O	10		5	10	15	10	5	5						?
Dry-CO_2	L	20	15	15	30	20									?
Gathering	S	30	20	20	50	30									?
Lines	O	50	35	35	80	50									?
Total	L	n.a.	21	75	120	175	120	25	25	10	10	10	10	10	
	S	n.a.	9	115	195	260	165	30	30						
	O	n.a.		40	45	95	60	5	5						

*Number is rounded to nearest 5.

Note: Blanks = zero
L = local.
O = outside the region.
S = semi-local.
n.a. = not appropriate.
? = unknown, but not higher than previous known year.

Table 3-13. EXPECTED COMPOSITION OF POPULATION INFLUX TO CORTEZ

Year	Total Unaccompanied New-to-the-Area	Weekly Commuters	# Persons in New Home Bases*	Estimated Total Project Related Population Increase	Cortez Population Projections without Project**	Population Increase over Current Population Projections (%)
1979		8		10	7015	0.2
1980	45	85	150	280	7300	3.8
1981	65	145	245	455	7450	6.1
1982	95	195	390	680	7600	8.9
1983	60	125	275	460	7800	5.9
1984	10	25	80	115	8000	1.4
1985	10	25	80	115	8200	1.4

*Rounded to nearest 5.
**October 1978 estimate by Cortez, Colorado City Manager.

located in Cortez, the population increase of 680 would amount to less than 9 percent of Cortez's projected population over the first 3 years of construction (Table 3-13). No short- or long-term adverse impacts are anticipated as a result of population increases of this size.

Secondary Employment. "Secondary employment" refers to those jobs most commonly created in retail and service sectors, (e.g., mechanics, clerks, waitresses) because of new service demands made by population increases. Some new employment opportunities are expected in secondary services due to project-related population increase; however, most of these new jobs would be filled by persons residing in the area or by spouses of project employees rather than by new people from outside the area. The expectation is based on two reasons, one related to the Cortez community, the other to the proposed project.

First, new secondary employment is generally a response to a gap between existing service levels and new demand for services. While Cortez is rural in character, it is the major tourist service center associated with Mesa Verde National Park (about 10 miles to the southeast) and has relatively high existing retail and service levels to accommodate the seasonal influx of tourists to the area.

Second, increased employment in secondary jobs is a function of the number of new-to-the-area people and the duration of the new project. The proposed project has three characteristics that would discourage new investment in Cortez by outsiders: (1) peak employement would be short (6 months), (2) the construction project would be short (mostly complete in 4 years), and (3) the operations staff would be small (20 new-to-the-area employees).

Housing. It is unlikely that any significant impact on housing in Cortez or Montezuma County would result from project-related population increases. The new demand for housing would be within local capacity, even during the peak year. Should all new-to-the-area employees who were accompanied by families want to purchase homes (which is unlikely given the short duration), only 110 homes would be involved; this number represents 3.0 percent of the housing stock in the county as of 1977. In the recent past, Cortez suffered shortages in various housing types. While a shortage remains of good, lower priced housing for sale, the housing supply has begun to increase and is expected to continue.* Furthermore, mobile homes are a common housing mode for construction families and the available sites for these are also increasing.

Unaccompanied employees tend to share rental quarters within daily commute distances from the project site. It is expected that most employees would seek shared rental quarters in and around Cortez, although a few may seek housing as far away as Durango (45 miles away).

*Personal communication with Cortez, Colorado City Manager 1978.

In 1976, rentals accounted for 26 percent of the county's conventional housing. Rental vacancies currently number about 150, with several multiple dwelling rental units under construction in the Cortez area.* The short-term housing demand would undoubtedly be partially supplied through the use of mobile home facilities. Construction employees often bring mobile homes or other live-in vehicles to a short-term construction job. Some new and available trailer pads already exist in the Cortez area, and space and public services are available for expanding these facilities with increasing demand.* Mobile home units are not considered a new form of housing in the area; they represented 20 percent of the total housing in Montezuma County in 1973.

No long-term impacts to housing are foreseen for the Cortez area as new housing construction would not likely be required to meet project-related demand. Though short-term housing needs could be met by existing facilities, the increasing demand for rental units would likely increase rental prices. It is unlikely that the 750 hotel and motel units in Cortez would be available for project-related use except by supervisory and inspection personnel on an occasional basis. Thus no tourist use of temporary housing is expected to be displaced by project-related demand.

<u>Public Facilities and Services</u>. Unlike many, more remote project sites, Cortez is served by a professional City Manager. In addition, a professional planning staff for the city is associated with the bi-county Montelores Planning Commission and the San Juan Basin (planning) Commission. Available professional expertise and the fact that the city of Cortez is in a healthy financial condition (Montezuma Valley Journal 1978) should enable the city to cope with the few new demands on infrastructure services. Since no new housing construction is anticipated, strain on existing infrastructural services would be negligible.

It is expected that no more than 110 children would enter the area schools. This number would increase the population of the Montezuma County Schools by 2.8 percent and would create no significant impact on the district.

<u>Human Expectations and Lifestyles</u>

Some local, employed persons would most likely shift from their present jobs to the higher paying construction jobs associated with the proposed project. It is probable that job vacancies would be filled by persons who are currently not in the labor market, or who are under-employed or unemployed.

The new employment opportunities in the area would possibly create shifts in lifestyles: more women would be likely to assume jobs;

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*Personal communication with Cortez, Colorado City Manager 1978.

marginal agricultural workers may assume new jobs; and some drop in local unemployment should occur. Given the local experience with seasonal tourist trade, these employment shifts probably would not create long-term problems. Some local employers may have to train less experienced persons to fill job vacancies, but their efforts presumably would be balanced by an increase in business. The net effect created by new local employment is likely to benefit the area by increasing revenues of business and relevant taxing jurisdictions.

The proposed project undoubtedly would cause other local effects on the Cortez community. For instance, the number of new people would likely create a year-round atmosphere similar to the busier weeks of the summer tourist season in the area. Some drop in seasonal tourist trade could result from use of hotels, motels, and recreational vehicle facilities by some of the new employees. Retailers who cater to tourist gift buyers may need to adjust their stock of goods. Some service and retail employers would need to hire year-round staff to levels now employed only during the summer. Programs and activities that rely on volunteers could be hindered as more area residents would work for wages. While some citizens would feel disenfranchised by the new atmosphere created by "strangers", others would foster new friendships. Some new capital investment could provide new opportunities for all residents, responding to year-round stability in demand for goods, services, and entertainment. These and similar changes cannot be specificially predicted; they would result from individual adjustments to the changing social and economic environment.

Income and Expenditures. The total project payroll is expected to be approximately $3.5 million. Assuming that about 25 percent of this amount would be paid in state and federal personal income taxes, the resulting disposable income would total about $2.6 million.

The city of Cortez would benefit from retail purchases and expenditures made by construction workers. Because the construction period is of relatively short duration, few major items such as homes and durable goods would be purchased; however, there would be expenditures for temporary housing and consumables such as food, fuel, clothing, and entertainment. Assuming that expenditures of new-to-the-area employees would total about 25 percent of their disposable incomes, the impact on local retail receipts from the project work force would be $390,000 over the four years of intensive construction activity. In addition, the construction project itself would require local purchases of fuel, small tools, and office supplies. This would generate some small increases in revenue to the local jurisdictions and business.

The average local expenditures for the project are expected to be lower than those for many construction projects because a large number of employees would likely be weekly commuters; their wages would be sparingly spent in the local area. Locally-hired employees, however, would be likely to spend a high proportion of the total disposable project payroll (about $1 million) in or near Cortez.

While the cost of some items and services may be affected, current residents generally should experience no sharp increases in prices nor decreased availability of day-to-day necessities. Spending patterns for durable goods are not likely to change since these pruchases are often made at nearby population centers, Grand Junction and Durango.

Fiscal Effects. Monies accruing to state and local tax jurisdictions (including relevant tribal and trust lands) as a result of the construction of the CO_2 well field would be generated by state and personal income tax, state sales tax, state production and conservation tax, and local property tax. The increase in state personal income tax would be less than .01 percent per year. Sales tax revenues from personal expenditures would also be slight. It is not possible to estimate the sales tax revenues resulting from the purchase of materials used in construction.

Construction in the CO_2 well field would increase local property tax revenues. The state of Colorado assigns a market value to the physical facilities, to which the counties involved apply the following general tax formula:

30 percent of market value x county mill levy = tax

For Dolores and Montezuma counties, this is an average tax levy of 2 percent of total market value. Based on the general formula, the estimated annual taxes generated are $200,000 and $472,000 for Dolores and Montezuma counties, respectively. Dolores County would experience the greatest fiscal impact from the proposed project; its estimated tax revenues would be approximately 18 percent of total county revenues ($2,605,944 in 1975). Only a small increase in property tax revenues would accrue to jurisdictions owned by either the Mountain Ute Indians or the Southern Ute Indians since no wells and only about 2 miles of gathering lines would be routed through tribal areas.

Operation

Operation of the CO_2 well field facilities would require only about 40 employees, half of whom would probably be hired from the local area. About 20 employees would be transferred to the local area and assume residence for at least 10 years. This number of new-to-the-region employees is small and would not increase the population sufficiently to affect the infrastructure of the Cortez area. Well field operation would, however, result in long-term beneficial impacts to the taxing jurisdictions of Dolores and Montezuma counties.

Summary

The analysis suggests that the project-related population influx would be small (680 people for peak construction) and the duration of stay would be short. The resulting effects would not produce lasting

adverse impacts in the CO_2 well field area. If all new persons, including weekly commuters located in the city of Cortez, the population increase would amount to less than 9 percent in the third and peak year of project construction.

Short-term effects associated with the influx of construction employees would impact the temporary housing market in the area. Rents would increase as the demand for mobile housing facilities and other forms of temporary housing grew. Tourist displacement in temporary housing would be minimal since most tourists would continue to be accommodated by local hotels and motels which operate at capacity during the summer tourist peak.*

Both short- and long-term beneficial fiscal impacts would accrue to taxing jurisdictions of Dolores and Montezuma counties and to Cortez merchants. Project-related tax revenues for the two counties would be substantial; for Dolores, one year of taxes represents 18 percent of 1975 total revenues. During the four primary years of construction, Cortez merchants would experience about a $400,000 increase from disposable income spending by new-to-the-area project employees.

CO_2 PIPELINE

Construction

In general, most aspects of the socioeconomic environment would be substantially or entirely unaffected by the construction of the pipeline. Conventional underground pipeline construction is rapid, labor intensive, and conducted by several spreads simultaneously. In rural areas, such as the Colorado-New Mexico-Texas area of this project, construction spreads can cover as much as two miles per day.

Construction of the proposed pipeline is estimated to take about 6 months. Pipeline construction would be accomplished by five teams ("spreads") working simultaneously in five different areas along the pipeline route. Due to the construction sequences and estimated rates of work progress, the peak employeemnt of 250 workers for each of the pipeline spreads is not expected to exceed 2 months.

Each spread would be responsible for constructing pipeline segments approximately 100 miles long; the crews would commute less than 100 miles from headquarter cities to the work sites;** temporary field camps would not be needed. (Likely headquarter cities for the crews would be Farmington, Albuquerque, and Roswell/Hobbs, New Mexico.)

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*Personal communication with Cortez City Manager, February 1978.

**Daily commuting of over 100 miles for similar projects is not uncommon (Construction Workers Profile 1975).

Approximately 60 percent of the labor force required for the proposed pipeline would be skilled and may have to be hired from outside the headquarter cities. About 100 lesser skilled workers would be hired from the Farmington-Bloomfield-Aztec area, 200 from the Albuquerque metropolitan area, and 200 from the Roswell/Hobbs vicinity (Table 3-14).

Table 3-14. TWO-MONTH PEAK WORK FORCE FOR PIPELINE SPREADS

Spread	Headquarter City	Number of New-to-the-Area Employees	Local Employees
Well field to Aztec	Farmington	150	100
Aztec to Bernalillo	Albuquerque	150	100
Bernalillo to Vaughn	Albuquerque	150	100
Vaughn to Roswell	Roswell/Hobbs	150	100
Roswell to Oil field	Roswell/Hobbs	150	100

These jobs would represent about 3 percent of the reported contract construction work force for 1974 to 1975 near Farmington, less than 2 percent for Albuquerque, and less than 10 percent for Roswell/Hobbs. In addition to labor requirements for pipeline construction, about 30 additional workers would be needed to construct a compressor station in Sandoval County, New Mexico. These employees are likely to be hired from the Albuquerque area and would commute to the site on a daily basis.

Population. Since the period of employment is short (2-month peak), only a small group (less than 10 percent) of new-to-the-area employees would bring spouses or families with them. At most, additional population influx related to pipeline construction would amount to 180 persons in the Farmington area, 360 in Albuquerque area, and 360 in the vicinity of Roswell/Hobbs. These figures assume that 10 percent of the new-to-the-area employees would bring families averaging three members.

Secondary Employment. Pipeline construction is not expected to have any short term or lasting impacts on local employment rates or to create new opportunities for secondary employment.

Housing. Housing would normally be provided through the use of mobile home or camper spaces and temporary rentals (e.g., hotels, motels, small apartments). Even in the worst case, new demand for services in the three headquarter urban areas would be insignificant.

Income and Expenditures. The projected total income for pipeline and compressor station construction personnel is $18.7 million. Assuming that approximately 25 percent of total income would go to state and federal income taxes, approximately $14 million would remain as disposable income for the total construction force. This is a low estimate since it does not include salaries of pipeline inspectors or administrative and support staff.

Since the five spreads would operate out of separate locations along the pipeline route, no one community would receive total benefit from disposable income generated. Because the construction project is relatively short in duration and many construction personnel would be only temporary residents in the area, it is doubtful that there would be any local investment in homes or durable goods. Individual purchases of such commodities as food, fuel, clothing, rental housing, and entertainment would be made. In addition, the construction spreads would make local purchases of fuel, small tools, and office supplies.

Assuming that 25 percent of disposable income would be spent on temporary living expenses, non-local construction employees would spend an estimated $2.1 million over the 6 months of pipeline construction. Of this, about $420,000 would be spent in the greater Farmington area and $840,000 would be spent in each of the two headquarter areas of Albuquerque and Roswell/Hobbs.

Employees to be hired locally would have total disposable incomes of $1.1 million in the Farmington area and $2.2 million in each of the two other headquarter cities. A high proportion of this income would most likely eventually be spent in the respective areas on durable goods and housing improvements as well as for living expenses.

Fiscal Effects. Additional revenues resulting from construction of the CO_2 pipeline would accrue principally to the counties or Indian jurisdictions as a result of increased property values. In La Plata County, Colorado (using the formula detailed previously in this section) the result would approximate $42,000 in additional annual income for the county. The impact on county revenues would be insignificant as the estimated tax is less than 1 percent of present total revenues ($5,300,658 in 1975.

The various counties and Indian tribes in New Mexico would receive property tax revenues based on the assessed value of the pipeline and support facilities located within their boundaries. The annual county property taxes estimated on the basis of assessment rates and tax levies are: San Juan, $25,100; Sandoval, $52,520; McKinley, $6530; Bernalillo,

$4130; Santa Fe, $260; Torrance, $23,350; Guadalupe, $2330; Lincoln, $5690; Chaves, $33,230; and Lea, $12,970. The property tax revenue that would be generated by the pipeline and facilities is not expected to have any significant impact on total county revenues.

In addition, the state of New Mexico would collect a gross receipts (sales) tax of 4 percent of the cost for materials and construction services related to the construction of the pipeline through the state. Individual counties and municipalities have the option of imposing an additional gross receipts tax of 0.5 percent and 0.25 percent, respectively. Consequently, the tax in any given taxing jurisdiction could range between 4 and 4-3/4 percent of the construction costs.

In Texas, the additional property value subject to property tax as a result of the construction of the pipeline facilities would be negligible. The state would, however, collect a 4 percent sales or use tax on the cost of materials incorporated into or used in the construction of that segment of the pipeline within Texas. No estimate of the resulting revenue is possible.

Operation

Operation of the pipeline and associated facilities would require approximately 24 persons. No perceptible impacts are anticipated from a work force so small and dispersed.

Additional tax revenues from the pipeline would accrue principally to the counties as a result of increased property values. The amount of annual tax revenue per county varies from about $4000 to $52,000 depending on the number of miles of pipeline in each county.

Summary

Constructing the pipeline would be a short project (2-month peak) that would require relatively few new-to-the-area employees (750 at most). These employees would be housed simultaneously in three New Mexico urban areas: 150 in Aztec-Bloomfield-Farmington; 300 in the Albuquerque metropolitan area; and 300 in the vicinity of Roswell/Hobbs. No significant adverse impacts are anticipated from a short-term work force so relatively small and dispersed.

The primary impact associated with constructing and operating the pipeline facilities would be fiscal. This fiscal impact would be both beneficial and relatively long term. Additional revenues resulting from the pipeline would accrue principally to the counties as a result of increased property values. The amount of tax revenues gained by each county would be a function of the number of pipeline miles running through it. The annual dollar amounts would range from about $4000 to $52,000.

OIL FIELD

Construction

Most construction projects in the Denver City-Wasson Oil Field area related to the CO_2 project would last about one year. In 1981 the peak work force would consist of about 480 people; some of the projects would extend into the first half of 1982. Of the 480 jobs, all but 20 percent are expected to be filled by available workers within daily commute distances (Table 3-15). About 95 jobs may require specially skilled persons to be employed from outside a daily commute distance.

Table 3-15. OIL FIELD CONSTRUCTION WORK FORCE REQUIREMENTS

Construction Project	Number of Employees Presently from Oil Field Commute Area	Number of Employees Estimated to be New-to-the-Area
Gas-Gathering Compressors	30	10
Recompressors	65	15
Production Facilities	30	10
Lines	80	20
Processing Plant	160	40
Construction Totals	365	95

Population. Hobbs, New Mexico in Lea County would be the most likely place of residence for new-to-the area employees. Hobbs is about 30 miles from the construction area and is the current center for services to the oil field area. The addition of 95 employees to Lea County represents an addition of less than 0.5 percent to the county's 1975 civilian labor force figures.

Housing. Given the short duration of the construction period, demand for purchased housing is not expected to increase. The addition of 330 people,* including some family members, is not likely to produce

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*This worst-case estimate is based on the assumption that 85 percent of the new-to-the-area employees would bring families of 3.9 members. The remaining 15 percent would be unaccompanied. Given the short duration of the project, this estimate of family members is probably high. No secondary employment is expected to accompany the small population influx.

significant social or economic impacts to the area, which already houses about 50,000 people.

Fiscal Effects. The potential property value increase that would result from the CO_2 injection project and subsequent increase in oil and gas production cannot be estimated at this time. Should the project be successful and the production of oil and gas increased, the state would realize additional production taxes. At the same time, the local governments would have a larger value base and greater income from the imposition of the property tax.

Other Impacts. Other social and economic characteristics of the area are not likely to be affected by so small an influx.

Operation

Operation and maintenance of the new facilities at the oil field are functions which are likely to be performed by existing oil field staff. The change in oil recovery techniques utilizing the CO_2 would be likely to extend the life of the field and the duration of existing employment.

Summary

Given the short duration of the construction period and the availability of an appropriate labor force within daily commuting distance from the project site, no adverse impacts are found to be associated with the oil field element of the project. The main effect of the project would be the temporary location of 330 people or less than 95 households in Hobbs, New Mexico. This additional population represents less than 1 percent of the county's 1975 population. Thus no social or economic impacts are anticipated for the area.

The fiscal impacts associated with the oil field cannot be quantified at this time because the effect of CO_2 injection on oil production is uncertain. If there were fiscal impacts, they would be the beneficial result of taxes levied on additional production and property.

IMPACT CONCLUSION

The proposed project would cause a short-term increase in population, mostly in Cortez, Colorado where the increase would be about 9 percent or less for a period of about 1 year. Population increases in areas along the pipeline route and near and oil field would be negligible. The population increases near Cortez would have negligible impacts on housing and on public facilities and services.

The greatest impact of CO_2 development would be fiscal. Increased assessed valuations and tax revenues would accrue to local government jurisdictions.

CHAPTER 4

MITIGATING MEASURES NOT INCLUDED IN THE PROPOSED ACTION

FEDERAL

This chapter discusses mitigating measures (Table 4-1) in addition to those measures discussed in Chapter 1, Proposed Action. Thus many mitigating measures, especially for more potentially significant impacts (e.g., archaeology, erosion) have been made an integral part of Chapter 1 (e.g., erosion control devices) or attached as a stipulation to Authorized Actions (e.g., archaeological surveys).

Federal field compliance officers will conduct field inspections to ensure all stipulation requirements are met by the grantee and its contractors. During key construction periods, the compliance officer may be at a specific site until construction is completed. If the grantee/lessee violates the terms and conditions of the right-of-way grant, the federal agency may issue immediate orders to suspend operations in order to protect public health and safety and the environment.

BUREAU OF LAND MANAGEMENT

1. Measure: Selectively apply water to access roads and rights-of-way during periods of heavy construction traffic on dry, windy days.

Impact to be mitigated: An unquantifiable increase in fugitive dust would be generated by earth-moving and other construction equipment in the CO_2 well field and along the pipeline right-of-way.

Effectiveness of measure: Fugitive dust would be reduced by an estimated 50 percent.

2. Measure: Bend pipeline at each side of highway crossing at U.S. Highway 54.

Impact to be mitigated: Rights-of-way crossing highways without bends can create a long tunnel view of the right-of-way. This contrast exceeds the VRM Class III rating at the U.S. Highway 54 crossing.

Effectiveness of measure: Reduction of visible contrast would allow the affected area to meet its previous VRM rating.

3. Measure: On drill pads and building sites, remove vegetation on an irregularly shaped area.

Table 4-1. SUMMARY OF MITIGATING MEASURES

Impact	Mitigating Measure	Impact Reduction due to Mitigation
Increased levels of fugitive dust on cleared areas during construction periods	Apply water to cleared areas during dry, windy days	Reduces fugitive dust levels by an estimated 50 percent
Possible abandonment of active raptor nest within 1/4 mile of blasting at construction sites in Doe Canyon portion of CO_2 well field area	Avoid blasting within 1/4 mile of active raptor nests between March and July	Greatly reduces likelihood that raptor nest would be abandoned due to construction noises
Reduction of visual quality of landscape at U.S. 54 highway crossings	Place bend in pipeline on each side of crossing	Reduces contrast (that exceeds Class III objective) associated with long, tunnel view of the right-of-way
Reduction of visual quality near drill pads and building sites where vegetation must be removed	Remove vegetation on an irregularly shaped area rather than a square, rectangle, etc.	Enhances resemblance of cleared area to a natural opening in the vegetation, thus reducing noticeable contrast
Destruction, alteration or damage to subsurface cultural resources during pipeline construction	Monitoring of high probability areas by archeologist of pipeline trenching	Reduces potential for complete loss of any subsurface cultural resources encountered

Impact to be mitigated: Clearing vegetation on a rectangular or similar shaped area with straight sides increases the contrast between the cleared area and adjacent undisturbed areas.

Effectiveness of measure: Cleared area for well pads and building sites would resemble naturally occurring openings in the vegetation in order to reduce the visual contrast.

4. Measure: Archaeologist to monitor pipeline construction in areas identified during cultural resource survey as having a high probability of containing subsurface cultural sites.

Impact to be mitigated: Disturbance of subsurface cultural material.

Effectiveness of measure: Minimizes potential for complete loss of affected subsurface cultural resources.

STATE

COLORADO DIVISION OF WILDLIFE

1. Measure: Within the Doe Canyon portion of CO_2 well field, avoid blasting within 1/4 mile of an active hawk nest from March to July.

Impact to be mitigated: Blasting near an active raptor nest may cause the nest to be abandoned.

Effectiveness of measure: This mitigation measure is expected to eliminate the abandonment of active nests by raptors as a result of nearby blasting during well field construction.

CHAPTER 5

UNAVOIDABLE ADVERSE IMPACTS

AIR QUALITY

Construction of the proposed project would result in a temporary adverse impact to the air quality near construction sites as a result of the emissions of fugitive particulates and gaseous pollutants.

Particulate emissions in the CO_2 well field, along the main pipeline route, and in the oil field are estimated to be 530 tons, 438 tons, and 335 tons, respectively, during a worst case year. Since dry soil conditions are common to all these areas, construction operations would contribute to intermittent violations of ambient air quality standards during periods of high wind speed.

Carbon monoxide (CO) would be emitted in larger amounts than any other gaseous pollutant. Emissions in the CO_2 well field, along the main pipeline route, and in the oil field are estimated to be 696 tons, 860 tons, and 773 tons, respectively, during a worst case year. All gaseous emissions would be intermittent, transient, and would not affect regional air quality.

Operation of the CO_2 well field and the oil field would result in unavoidable adverse impacts on the air quality as a result of gaseous emissions. These emissions would be produced at the central facilities in the CO_2 well field and at the compressors in the oil field.

The major emission from the CO_2 well field would be sulfur dioxide (SO_2). During an average year, about 57 tons of SO_2 would be emitted. This would lead to a maximum annual increase of about 5 $\mu g/m^3$ in SO_2 concentrations, which is below the Colorado annual incremental SO_2 standard of 10 $\mu g/m^3$ for Category II regions. This standard is the most restrictive standard applicable to the CO_2 well field. The emissions of other gaseous pollutants would be at least 50 percent less than SO_2 emissions and no violations of state or federal standards would be expected.

The major emissions resulting from the operation of the oil field would be nitrogen oxides (NO_x). Annually, as much as 4070 tons might be emitted. This would lead to a maximum annual concentration increase of about 78 $\mu g/m^3$, raising the ambient NO_x concentrations in the area to a maximum of about 94 $\mu g/m^3$. Since NO_2 concentrations will be lower than NO_x concentrations, the annual NO_2 concentrations would be below the federal ambient standard of 100 $\mu g/m^3$. Other emissions are no larger than 1/3 of the NO_x emission and no violation of federal or state standards would be expected.

PALEONTOLOGY

The construction of the pipeline and CO_2 well field would use blasting, ripping, and excavation of possible fossil bearing rocks. There would be no means of determining where a fossil existed prior to blasting. There would be no means of determining when a fossil had been encountered during excavation; excavation would obliterate the fossil remains.

The destruction of any fossils encountered during the construction of the proposed project would be an unavoidable adverse impact.

SOILS

Construction of the proposed project would result in an unavoidable impact on soil due to increased water and wind erosion on areas where the vegetative cover and upper soil layers have been removed or disturbed. The increase in water-induced soil loss over the 30-year life of the project is estimated at 49,500 tons for the well field area, about 9,600 tons for the main CO_2 pipeline right-of-way and 49,800 tons in the oil field. The total of 109,100 tons attributed to the project is about 330 percent more than would occur without the proposed project. Wind erosion will also increase an unquantifiable amount but would be minimized during construction activities by watering the dirt roads and other cleared surfaces as appropriate.

WATER RESOURCES

While some minor increases in localized stream turbidity would occur during construction at river crossings, no water resource impacts of major significance are expected to occur. The increase of in-stream sediment loads is predicted to vary from <0.01 to 0.30 percent above existing annual in-stream loads for streams affected by the proposed project. In-stream suspended sediment levels would be increased for about one to three days in the vicinity of the stream crossings, but would approach pre-crossing levels within several thousand feet downstream of the crossing.

VEGETATION

Project construction would result in the temporary loss of about 6551 acres of vegetation. This total includes 2276 acres of vegetation in the CO_2 well field, 2980 acres along the main CO_2 pipeline clearing (average width of 50 feet) and associated facilities, and 1295 acres in the oil field. Revegetation on 94 percent (6154 acres) of the disturbed area would begin following construction activities. The remaining 6 percent (397 acres) would be occupied by above ground facilities (central facilities, origin station, compressor station, and injection facilities) for the 30-year life of the project.

FISH AND WILDLIFE

Removal of vegetation during project construction would result in the loss of about 6551 acres of wildlife habitat. A loss of some fish and wildlife would occur primarily during vegetation clearing operations. A few animals may also be lost as a result of collisions with vehicles.

The only crucial wildlife habitat that would be temporarily affected by the proposed project consists of less than 25 acres of crucial elk and mule deer winter range in the Doe Canyon Field and a 50-ft wide area of principal winter range for mule deer near the Continental Divide in northwestern New Mexico. The temporary removal of this crucial habitat is expected to have a minimal impact on these big game populations.

Impacts to fish and other aquatic organisms are expected to be insignificant since disturbances to aquatic habitats at the stream crossings are small in area and short in duration.

Although the proposed project is within the distribution of six federally designated endangered wildlife species (peregrine falcon, bald eagle, whooping crane, black-footed ferret, Pecos gambusia, and Colorado River squawfish), project construction is not expected to have any adverse or unavoidable impacts on any endangered or threatened species of fish or wildlife.

CULTURAL RESOURCES

Although all construction sites will be surveyed prior to any surface disturbances to ensure that no significant archaeological or historical sites are present, it is possible that some unquantifiable number of cultural resources having no surface manifestations may be destroyed or damaged during construction activities. The increased ease of access as a result of new and improved roads in the CO_2 well field may increase the potential for vandalism of archaeological sites, especially by pot hunters.

VISUAL RESOURCES

Construction activities would cause unavoidable impacts to visual resources throughout the project area. Revegetation of cleared areas in the well field would reduce the visual impacts in agricultural areas in 1 to 2 years and 5 to 15 years in most remaining areas. Selective clearing at central facilities and well sites would reduce the total impact but most central facility sites would continue to exceed the designated VRM class objective for the 30-year life of the project. Visibility of the pipeline right-of-way is expected to diminish as natural revegetation progresses, however, about 80 percent of the impacted viewsheds would exceed designated VRM class objectives permanently.

WILDERNESS VALUES

Construction of a dry-CO_2 gathering line across the Dolores River is expected to have a minimal adverse impact on the wilderness qualities of the proposed Dolores Wild and Scenic River. Placement of the pipeline along draws and revegetation (including tree plantings) are expected to camouflage the right-of-way so that few rafters on the Dolores River would be aware of its presence.

RECREATION RESOURCES

The increased ease of access especially in the CO_2 well field may reduce some recreational qualities (for example, hiking) and increase others. Adverse recreational impacts in the project region should be minor.

AGRICULTURE

Project construction would result in an unavoidable loss of livestock forage and agricultural production. Clearing of vegetation on grazing lands would reduce the annual number of AUMs by 480 immediately after construction. The total of about 4010 AUMs that would be lost during the life of the project until vegetation becomes reestablished is not expected to have any adverse impacts on any livestock operations since the reduction in AUMs is minor in any one area. Construction would also result in the disruption of approximately 1212 acres of farmland, of which 1134 acres could be returned to productivity in about one year.

MINERAL RESOURCES

Some of the CO_2 injected into the oil field would not be recoverable and therefore not available for further use.

TRANSPORTATION

Construction and operation of the proposed project would require some existing roads as well as the construction of some new access roads in the CO_2 well field. There would be some increased road use caused by the movement of employees and materials to and from the job sites. Traffic on major highways would not be affected since the pipeline would be tunneled or bored under the highways.

SOCIOECONOMIC CONDITIONS

Construction activities would create an increase in employment opportunities for a 1- to 2-year period. Since most of the labor requirements are expected to be fulfilled by the local labor markets, few workers are expected to migrate into the area. Thus the effects of these additional workers are not expected to result in any significant adverse impacts to the socioeconomic conditions of the project region.

CHAPTER 6

THE RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

INTRODUCTION

For analysis purposes, "short term" is defined as the period to construct, implement rehabilitation measures, and place the project in operation. This would be a 6- to 9-year period, including the implementations of rehabilitation measures. "Long term" is considered to be the life of the project, or an estimated 30 years in the case of the proposed CO_2 project. Although 30 years is the anticipated length of the project, the actual long-term effect of a project of this magnitude is assumed to be permanent.

CUMULATIVE IMPACTS

In conjunction with the Dolores Project, cumulative impacts are expected to occur as a result of archaeological studies currently being conducted for that project. In addition, a predictive model was developed for the archaeological resources involved in this proposed CO_2 project. The information gained from either of these studies should benefit the other, and together they should significantly affect the knowledge of regional archaeological resources.

TRENDS

Implementation of the proposed CO_2 project would create and improve access roads and rights-of-way. This action is expected to:

- perpetuate existing uses
- encourage various types of development

An additional trend may be the injection of CO_2 into other oil fields.

BENEFITS

Cultural Resources

Long-term benefits would be realized from information gained during archaeological surveys, excavations, and other cultural investigations generated by this proposed project.

Minerals

Long-term benefits would result from oil extracted during this project. As of August 1977, the Denver Unit had produced about 560

million barrels of oil using primary and secondary recovery techniques. Secondary waterflood-induced production peaked at 151,000 barrels per day in November 1975 and is presently declining. Of the 2.108 billion barrels of original oil in place, it is estimated that approximately 750 million barrels (36 percent of the oil in place) would be produced by the ongoing waterflood, leaving approximately 1.360 billion barrels in the reservoir. It is estimated that implementation of the proposed project would provide an additional 280 million barrels of oil through the miscible CO_2 tertiary recovery program, thus increasing recovery from the Denver Unit from 36 to 50 percent of the original oil in place. The proposed tertiary CO_2 flood would not completely replace the ongoing secondary waterflood; these enhanced oil recovery techniques would operate in conjunction with one another. Implementation of the CO_2 flood would decrease the production decline projected for use of ongoing waterflood methods only, as well as cause a net increase of oil production and lengthen the life of the field.

Socioeconomic Factors

Transportation. Long-term benefits would include the addition of new access roads to the area and the improvement of existing roads.

Political, Technical, and Economic Considerations. Long-term benefits from the proposed project would include increased crude oil production from the Denver Unit of the Wasson Oil Field and income to counties in which the project would be situated. Benefits from enhanced recovery programs are:

- Domestic Energy Policy. Any increases in domestic oil production will help reduce foreign import requirements and permit scaling back of emergency oil storage programs.

- Expanded Use of Enhanced Recovery Technology. Successful development of enhanced recovery technology for U.S. oil fields probably would demonstrate the applicability of technology in oil recovery processes to other fields.

- Flow of Tax Revenues. Severance, royalty, and property taxes imposed on enhanced recovery projects would contribute to the funding of government services.

- Employment. Short-term employment would be provided during the construction phase of the project. New long-term employment would be provided in the CO_2 production field and the period of employment for present positions in the Wasson Field would be lengthened. Approximately 6000 person-years of employment would be provided over the 30-year economic life of the project.

TRADE-OFFS

Minerals

The proposed action would use a nonrenewable source of CO_2 gas from the McElmo and Doe Canyon Fields. The use of this resource would mean that future potential uses of the gas in place would be eliminated. The estimated 30 year life of the project is based on the anticipated amount of recoverable oil in the Denver unit.

The appearance of CO_2 at the well heads in the Wasson Oil Field (mixed with water and produced oil) would make some of the gas available for other uses. It is possible that some of the gas could be used for other similar enhancement projects in other oil fields. The technology of CO_2 enhancement of oil production is still evolving; it is impossible to estimate how much of the CO_2 gas would be used for other projects, or for industrial uses.

Vegetation

Implementation of the proposed project would remove approximately 6551 acres of vegetation. Revegetation would restore cover to all but 6 percent (that which is covered by permanent structures) of the disturbed area. After the 30-year life of the project, some of the permanent structures may be removed and the land surface revegetated; other structures would probably remain for other uses. Thus some unquantifiable permanent loss of vegetation would occur on permanent sites not revegetated.

Revegetation would not be completely effective in all instances; partial or total failure in some portions of the proposed right-of-way would result in permanent vegetation loss to those areas.

Fauna

The proposed action would affect wildlife resources by altering habitats and by increasing noise and human presence. Loss or displacement of some large mammals, small mammals, and birds as a result of habitat disturbance would be minimal. Interference due to noise and human presence would displace or disturb an unquantifiable number of animals. Most habitat disturbances would be short term and occur during the construction period of the proposed project. Long-term disturbances would affect an unquantifiable number of wildlife sensitive to the presence of humanity.

Endangered and threatened animal species that may be affected by the proposed project include the peregrine falcon, bald eagle, whooping crane, Pecos gambusia, Colorado River squawfish, and black-footed ferret. Some unquantifiable disturbance could occur to potential habitat of the black-footed ferret, although none of this species are known to inhabit the project site. Peregrine falcons, bald eagles, and whooping

cranes, although occasionally observed in the project area, are not known to nest there.

The proposed stream crossings would disturb aquatic habitat for a few thousand feet downstream. Some short-term impact would occur to fish and other aquatic organisms known to inhabit these streams. No long-term effects would be anticipated.

Cultural Resources

Implementation of the proposed project could potentially destroy some historical, archaeological, or paleontological remains during construction, thereby causing long-term losses of these resources. Information on the cultural resources discovered as a result of this project may be lost because some sample items could not be preserved until some future date when analytical techniques have improved. Indirect impacts (e.g., vandalism) to archaeological, paleontological, and historical resources may occur due to the increased access and numbers of people from the project in the area.

Visual Resources

The visual resources in the project area would be adversely impacted both in the long and short term.

Wilderness

Roadless areas in the project vicinity are described in Chapter 2, wilderness values. These areas are currently being considered for wilderness designation but have not yet been classified as such. Long- and/or short-term impacts could occur to these areas as a result of the proposed project, but specific impacts would not be known until the areas were located. Direct impacts would be avoided or mitigated.

Socioeconomic Factors

Energy on this project expended in the manufacture and transport of materials to the site would not be available for other uses. Gasoline (630,000 gallons) and diesel fuel (1,860,000 gallons) would be burned during the construction and operation of the proposed project.

RISKS TO HEALTH AND SAFETY

Accidents During Construction

Precautions would be taken during the construction phase to minimize the number of injuries that could be incurred by workers. Access to construction areas would be restricted to avoid injuries to the public.

Pipeline Accidents During Operation

The endpoint of impact discussions involving the operation of the proposed CO_2 pipeline has centered on the possibility of a rupture in the pipe which would allow major leakage of CO_2 to the atmosphere. There are two means of assessing the probability of a major leak in the CO_2 pipeline: (1) to compare the proposed CO_2 pipeline to an existing pipeline carrying CO_2 gas, and (2) to compare the proposed CO_2 pipeline to existing pipelines carrying petroleum liquids and natural gas.

The only major pipeline presently carrying CO_2 gas is a 16-inch, 220-mile pipeline from natural gas treatment plants in the Val Verde Basin of Southwest Texas to the SACROC Unit of the Kelly-Snyder Field in the Texas panhandle. No leaks of CO_2 gas have occurred since operations began in 1971 (Justen 1979). Since the proposed CO_2 pipeline would be engineered, constructed, and operated in a similar manner to the SACROC pipeline; the most likely occurrence of a major CO_2 leak is expected to be similar to the SACROC experience. That is, there would be no expectation of a major leak of CO_2 in the most likely case.

If a leak were to develop in the pipeline, the maximum amount of CO_2 gas that would be vented to the atmosphere (under the premise conditions below) would be about 89 million standard cubic feet (mmscf). The pipeline is expected to have about 32 valves along its length, corresponding to a between-valve pipeline length of 15 miles. A 20-inch diameter line having a pipe wall thickness of 0.562 inches would have an internal volume of approximately 10,300 cubic feet per mile. The CO_2 in the pipeline would vary in pressure between 1400 and 2000 psig; for the assessment of volumes of gas escaping due to a major pipeline rupture, an average pressure of 1700 psig and temperature of 80°F were the premised pipeline conditions. One cubic foot of CO_2 vapor would weigh about 54 pounds under these conditions. If a cubic foot of this vapor were to escape, it would be expected to expand to 466 standard cubic feet. A 15-mile pipeline segment would therefore contain approximately 72 mmscf of CO_2 under the premised conditions of temperature and pressure.

If a leak involving a major rupture of the main pipeline between two valves were to occur, it is premised that one hour would be required to secure shut off. At a daily transport rate of 400 mmscf, this one-hour period would correspond to about 17 mmscf. Backflow of gas from downstream portions of the pipeline was premised to be negligible. Therefore, the only other gas to be vented is the volume of gas isolated in the 15 mile section in which the leak occurred.

Based on data from the Interstate Commerce Commission (1976) and the Department of Transportation Office of Pipeline Safety (1976), an estimate of the probability of leakage from pipelines may be inferred. Based on statistics of leakages from pipelines carrying petroleum liquids and natural gas of all ages and conditions and in all parts of the country, the following probabilities were estimated: the possibility of an accident (which could lead to leakage of some volume

of CO_2 gas) would be 0.000945 accidents per mile of pipeline. For a 478-mile pipeline this would correspond to 0.452 accidents per year; or 13.5 accidents over the life of the project. It is probable that some leakage of CO_2 gas of unknown volume would occur about once every two years. Since this estimate includes pipelines of all ages and conditions, this represents the worst-case probability.

In the most likely case, no significant leakage of CO_2 gas would be anticipated over the life of the project.

Effects

Risks to health and safety from the proposed CO_2 project would be the result of a large-scale leak from the main CO_2 pipeline. Although CO_2 is not toxic, it is an asphixiant (i.e., it displaces and dillutes the oxygen content of air). Thus, leakage of CO_2 gas may have some risk to health of people and animals immediately adjacent to the main CO_2 pipeline.

The conditions under which the CO_2 gas would become a hazard are listed below:

- periods of no wind in very stable, cold, dry air
- an area of relatively high population of people and animals
- low lying land, such as a river bottom
- massive leakage of CO_2 from complete rupture of main pipeline

Should such a leak occur under the given conditions, it is unlikely that the event would be unnoticed. A leak of such size, with pressures and volumes of such magnitude, would create a tremendous amount of noise.

Concentrations of gas near the rupture would be very high. The exact concentration would depend on how fast the CO_2 could go from a highly compressed state, rapidly expanding and absorbing heat from the atmosphere, to a gaseous state at ambient temperature. The gas would be slightly heavier than air. If massive concentrations (i.e., greater than 90%) of CO_2 were to envelop a person, death by asphixiation could occur before that person could leave the area. If animals were trapped by fences or other obstructions in such CO_2 concentrations, death from asphixiation would occur.

QUALITY OF LIFE

Enhanced productivity of the Denver unit would result in the recovery of 280 million barrels of otherwise unrecoverable oil over the length of the project. This would increase revenues and help maintain or improve the quality of life. No services would be required to offset the increase in tax revenues.

RELATIONSHIP OF PROPOSAL TO NATIONAL ENVIRONMENTAL POLICY ACT (NEPA) GOALS

Probably the greatest areas of concern generated by the impacts that would occur from this proposal would be in the cultural environment and the aesthetic environment. There would be an unavoidable increase in access to areas of high archaeological sensitivity. The visual resource would be unavoidably impacted in certain areas by construction of the proposed pipeline. Table 6-1 presents the relationship between project impacts and NEPA goals.

Table 6-1. TRADE-OFFS BETWEEN IDENTIFIED IMPACTS AND NEPA GOALS

	1. Fulfill the Responsibilities of Each Generation as Trustee of the Environment for Succeeding Generations	2. Assure for All Americans Safe Surroundings	3. Assure for All Americans Healthful Surroundings	4. Assure for All Americans Productive Surroundings	5. Assure for All Americans Aesthetically Pleasing Surroundings	6. Assure for All Americans Culturally Pleasing Surroundings	7. Attain the Widest Range of Beneficial Uses of the Environment without Risk to Health	8. Attain the Widest Range of Beneficial Uses of the Environment without Risk to Health	9. Attain the Widest Range of Beneficial Uses of the Environment without Risk to Health
Produce 280 Million Barrels of Otherwise Unavailable Crude Oil	Use of Resource is One-Time Opportunity			Maximum Recovery of Crude Oil in Place			Beneficial Use of CO_2 for Crude Oil Production		
Slight Decrease in Air Quality During Construction and Operation			No Significant Health Hazards						
220,000 Tons of Soil Erosion Attributable to Project	Not a Significant Loss of Future Productivity			No Significant Loss of Soil Productivity			Not a Significant Degradation of Soil Resource		
Temporary Deterioration in Surface Water Quality	Not a Significant Loss of Water Quality		No Risks to Health from Loss of Water Quality		Temporary Aesthetic Deterioration			No Ill Effects to Health Indicated	
Slight Risk to Ground Water of Cross Contamination in CO_2 Well Fields	No Indicated Uses of Groundwater Now or in Future		No Health Hazards Since No Present Use				Risk of Cross Contamination is slight		
2978 Acres of Vegetation Lost by Construction Temporarily	Temporary Loss of Vegetation				Visual Deterioration for Life of Project				
Temporary Loss of 2978 Acres of Wildlife Habitat During Construction	Temporary Disturbance Only			Slight Loss in Productivity of Wildlife			Loss of Habitat Would Not Be Significant		
Loss of Some Archeological Sites Not Visible from the Surface	Information Loss Would Be Permanent But Not Significant					Some Loss of Cultural Resource	Loss of Sites Does Not Degrade Knowledge of Culture		
Disturbance of the Visual Resource Along the Project Right-of-Way	Loss Would Be Significant Over Life of Project				Loss of Aesthetic Value		Degradation of Visual Environment		
Permanent Loss of the CO_2 Resource from the CO_2 Well Fields	Opportune Use of CO_2 for Enhanced Oil Production			Maximum Production of Crude Oil in Place					
Increased Access to the Archaeological Sites by Well Facilities Access Roads	Endangers the Arch. Resource By Looting By Vandals						Danger to Archaeological Resource By Vandalism		
$400,000 Spent in Cortez, Colorado by New Project Employees Over 4 Years				Increases Productivity of Local Economy			Benefits to Local Economy		
Additional Revenues to the Counties Along the CO_2 Pipeline Right-of-Way from Taxes				Benefits Local Economies					
Slight Risk of Leak or Rupture of Pipeline		Slight Risk to Health and Safety of People Near Right-of-Way	Slight Risk to Health from CO_2 Leaks					Slight Risk of Major CO_2 Leak	Some Risk to Safety from CO_2 Leakage

10. Attain the Widest Range of Beneficial Uses of the Environment without Undesirable Consequences	11. Attain the Widest Range of Beneficial Uses of the Environment without Unintended Consequences	12. Preserve Important Historic Aspects of Our National Heritage	13. Preserve Important Cultural Aspects of Our National Heritage	14. Preserve Natural Aspects of Our National Heritage	15. Maintain an Environment Which Supports Diversity	16. Maintain Environment Which Supports Variety of Individual Choice	17. Achieve a Balance Between Population and Resource Use Which Will Permit High Standards of Living	18. Achieve a Balance Between Population and Resource Use which Will Permit a Wide Sharing of Life's Amenities	19. Enhance the Quality of Renewable Resources	20. Approach the Maximum Attainable Recycling of Depletable Resources
	CO_2 Gas is Clean, Non-Toxic, and Non-Polluting	No Impacts to Historic Resource				Production of Oil Maintains the Nation's Economic Health	Energy Production is Directly Related to Standard of Living	Beneficial Economic Effects		CO_2 is Reusable for Other Projects
Erosion is Undesirable But Not a Significant Amount	Loss Would Be Well Within Expected Parameters								Not a Significant Loss of a Renewable Resource	
Not a Significant Loss				No Significant Loss of Natural Environment					Not a Significant Loss of Renewable Resource	
	Since Present Uses Are Lacking, Consequences Do Not Exist									
Not a Significant Loss	Well Within Expected Parameters				No Loss of Rare or Endangered Vegetation				Vegetation Lost is Renewable	
Habitat Disturbance is Undesirable	Within Expected Parameters			Wildlife Would Not Be Permanently Lost					Wildlife Habitat Maintained in Long Term	
	No Way to Mitigate Potential Loss		Much Knowledge Would Be Gained By Pre-Construction Inventory		No Loss of Significant Sites			Knowledge Gained from Inventory		
Loss of Visual Resource Would Be Undesirable	No Way to Avoid Visual Consequences									
						CO_2 Loss is Traded for Oil Production	CO_2 Would Help to Maintain Nation's Economy			Loss of CO_2 from Southwest Colorado Would Be Permanent
Conflict with Undesirable Consequence			Risk to Cultural Heritage					Vandalism Decreases Sharing of Knowledge		
	Should Not Produce "Boom" Conditions				Benefits Local Economy		Benefits Local Standard of Living			
							Benefits Local Economies			

CHAPTER 7

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

This chapter examines the environmental costs in terms of materials, energy, land use, and human values that would be committed for the proposed CO_2 project. "Irreversible" is defined as incapable of being reversed; once initiated, use, direction, or condition would continue. "Irretrievable" means essentially irrecoverable; not reasonably retrievable and once used, not readily replaceable. "Costs" in this chapter implies commitment, or that quantity or portion of the environment that cannot be recovered once assigned to the project. "Commitment" focuses on portions, percentages, species, or categories without respect to specific individuals or sources. For example, the loss of certain individual plants or animals as individual living organisms may be irreversible and irretrievable, while the species or population may remain viable although temporarily diminished in numbers and diversity.

ENVIRONMENTAL RESOURCES

Approximately 6551 acres of vegetation would be lost by clearing the land involved in the project. Approximately 6174 acres would be revegetated following the initial construction period. Another 397 acres would be permanently committed to constructed facilities for the 30-year project life.

Although the herbaceous vegetation would be replaced through revegetation measures, the loss of 248 acres of forested land would be permanent. The forested lands that would be involved in the proposal are not commercial in value.

Net potential soil loss (that is, soil loss over and above that which is expected to occur naturally) is expected to equal 109,100 tons during the construction, operation, and rehabilitation phases of the proposed project.

There would be a loss of habitat for an unquantifiable number of large mammals, small mammals, and birds due to the construction and operation of the project. This number would be less than 1 percent of the populations of these animals in the affected environments.

There would be some unavoidable loss of fossils encountered during the construction of the proposed project. There would be no means of identifying where such fossils exist in the rock prior to excavation.

Hovenweep National Monument would receive limited additional use as a result of improved roads and an unquantifiable increase in numbers of recreationists in the CO_2 well field region.

An estimated 110 additional children would enter schools in the Cortez area. This number would increase the student population of the Montezuma-Cortez School District Re-1 by about 3.7 percent.

There would be 6000 person-years of employment involved in the 30-year life of the project.

Over the course of the pipeline life there would be a worst case possibility of 13 accidental leakages of CO_2 gas which would represent an unquantifiable risk to health and life.

ENERGY INPUT/OUTPUT RATIO

The proposed project would increase the available energy in the form of oil extracted from the Wasson Oil Field but would also consume energy during construction and operation of the facilities needed to extract this oil. Energy would be consumed for vehicular operations, CO_2 dehydration, and gas compression at both the well fields along the pipeline (Table 7-1).

Energy Output

The gross energy output in the form of 280 million barrels of crude oil during 30 years of operation is approximately 1.624×10^{15} Btu (Table 7-2).

Energy Input

Over the lifetime of the proposed project, the following energy requirements are expected for gas compression, gas dryers, vehicles and construction equipment, lease fuel, and gas processing plant (Table 7-2).

Gas Compression. Gas compression would consume more energy than other project components. Operation of the compressors would require an amount of energy equivalent to 3.401×10^{14} Btu over the 30-year life of the project.

Gas Dryers. Glycol gas dryers in the CO_2 well field would utilize fuel oil as a heat source. Two modes of operations are anticipated: start-up and operation. Start-ups are assumed to be required once each month for a duration of one hour, resulting in an annual fuel consumption corresponding to 8.225×10^8 Btu per year. The annual operation requirement is 5.782 $\times 10^{10}$ Btu per year; therefore over the life of the project (30 years), this heat input rate would amount to 1.759×10^{12} Btu.

Vehicles and Construction Equipment. This category of fuel usage is expected to be highest during the pipeline construction phase and then

Table 7-1. ENERGY RESOURCE COMMITMENTS FOR PROPOSED CO_2 PROJECTS

Consumption Source	Project Location	Energy Required	Proposed Supply
CO_2 Compressors	CO_2 well field	74,500 hp	Electric
CO_2 Compressors	Pipeline	7,500 hp	Electric
CO_2 Compressors	Oil field	120,000 hp	Natural gas
Gas Dryers (start-up)	CO_2 well field	68.54 mm Btu/hr	Fuel oil
Gas Dryers (operation)	CO_2 well field	6.6 mm Btu/hr	Fuel oil
Vehicles/Construction	Along pipeline route	1.86 mm gallons	Diesel oil
Vehicles/Construction	Along pipeline route	0.63 mm gallons	Gasoline
Process plant fuel	Oil field	8.5×10^9 SCF	Natural gas
Lease fuel	Oil field	31×10^9 SCF	Natural gas

Table 7-2. ENERGY INPUT/OUTPUT SUMMARY

Energy Consumption or Source	Energy Equivalent (10^{15} Btu)
Energy Input	
Compressors	0.34
Gas dryers	0.002
Vehicles, construction equipment	0.0003
Processing plant	0.0087
Lease fuel	0.032
Total	0.382
Output	
Crude oil	1.624
Net Gain	1.241

diminish to a small annual requirement (see air pollution section). For the purpose of an energy balance, however, the total figure over the 30-year lifetime of the project is most important. The total fuel requirement is estimated at 2.371×10^{11} and 7.55×10^{10} Btu for diesel and gasoline, respectively, for a total of 3.126×10^{11} Btu.

Gas Processing Plant. Fuel is required to separate water and CO_2 from the oil well streams. Water is removed for reinjection into the oil field, and gas treatment is required for removal of hydrocarbon vapors from the CO_2. The projected fuel requirement is 8.5 billion SCF of natural gas which corresponds to 8.764×10^{12} Btu, for the 30-year period.

Lease Fuel. This fuel would be used at the oil field, primarily for oil treatment and separation. About 31.0 billion cubic feet of natural gas would be required over the project 30-year duration of the proposed project. This quantity of gas represents a heat input of 3.196×10^{13} Btu.

Net Energy Gain

The proposed project would require an energy expenditure of about 3.829×10^{14} Btu and would produce 1.624×10^{15} Btu. This would result in a net increase in available energy of 1.241×10^{15} Btu. Thus for each unit of heat energy supplied to the project, about 3.25 units would be produced.

facilities and 3 annual "installment" requirements (year six oil field facilities). For the purposes of the energy balance, however, the major figure that is of most importance is the total input. Importantly, the total input requirement in million Btu is 9.3×10^{9} Btu and 1.58×10^{10} Btu for direct and indirect, respectively, for a total of 5.76×10^{11} Btu.

Gas Processing Plant. Fuel is required to generate steam and to drive the gas plant processes. Steam is required for re-injection into the oil fields, and gas compression is required for the removal of sulfur and gas from the oil. The projected fuel requirement is 6.9 billion cubic feet of gas per year which corresponds to 6.46×10^{12} Btu for the 30-year period.

Lease Fuel. Some fuel would be used at the oil field, primarily for oil treatment and compression. About 21.5 billion cubic feet of natural gas would be required over the 30-year duration of the proposed project. This quantity of gas represents a heat input of 2.198×10^{13} Btu.

NET ENERGY GAIN

The proposed project would require an energy expenditure of about 5.07×10^{13} Btu and would produce 5.626×10^{15} Btu. This would result in a net increase in available energy of 5.575×10^{15} Btu. Thus for each unit of each energy supplied to the project, about 111 units would be produced.

CHAPTER 8

ALTERNATIVES

GENERAL ALTERNATIVES

Other Methods of Enhanced Recovery

No known tertiary recovery method for the San Andres reservoir at Wasson Oil field other than that proposed is feasible. The National Petroleum Council report of December 1976, "Enhanced Oil Recovery: An Analysis of the Potential for Enhanced Oil Recovery from Known Fields in the United States - 1976 to 2000" (Haynes et al. 1976), lists the various enhanced oil recovery (EOR) techniques developed by industry and the screening criteria used to select potential EOR candidates. The only applicable method for the reservoir rock and fluid conditions at the Wasson San Andres reservoir is the CO_2 miscible process. Although chemical flooding and thermal recovery are considered viable tertiary recovery processes for some oil reservoirs, only CO_2 appears feasible for the relatively low permeability, low porosity carbonate oil reservoirs characteristic of the Denver Unit of the Wasson Field. Chemical flooding was rejected as a tertiary oil recovery process in the Denver Unit of the Wasson Field because of (1) low expected chemical slug injectivity and (2) high expected chemical consumption due to high surfactant retention on the reservoir's carbonate rocks. Thermal tertiary oil recovery was rejected because of the inefficient utilization of injected heat in the low-porosity rocks characteristic of the reservoir.

Other Sources of CO_2

The proposed action rests on the development of existing leases containing CO_2 in the quantity required for tertiary oil recovery. At this time there are no alternate CO_2 resources available.

Other Methods of CO_2 Transport

The transportation of large volumes of CO_2 over long distances can be accomplished by pipeline, as proposed, or by the use of railroad tank cars and tank trucks. The following discussion shows why the use of railroad tank cars and tank trucks is not a viable alternative.

Assuming a volume relationship factor of 500 for liquified CO_2 over CO_2 at standard conditions permits estimates of surface transportation shipping requirements. Transporting the required 400 million SCF of CO_2 per day by rail or truck would require an aggregate tank volume of approximately 600,000 cubic feet. For example, assuming the

average railroad tank car has a volume of 1300 cubic feet (10,000 gallons) and the average tank truck 650 cubic feet (5000 gallons), the surface transport requirements are 462 railroad tank cars per day or 923 tank trucks per day. Delivery of the daily requirement of CO_2 would thus require a very large number of railroad cars - approximately 1400 when travel time and offloading time are taken into consideration. Similarly, assuming tank trucks could make one round trip every three days, a fleet of more than 2700 would be required.

To ship CO_2 by rail, a new line would be required from the CO_2 well field to the nearest existing railway, a distance of more than 100 miles. Because of the high density of on-line railroad cars, it would be necessary to augment the existing rail lines across New Mexico, which would in effect eventually have greater impacts than those discussed for the proposed pipeline project. For example, the permanent installation of a railroad bed complete with tracks and ties means that a significant portion of the right-of-way could not be rehabilitated and that the entire right-of-way could not be returned to its previous use upon completion of construction. The visual impact would be greater due to construction impacts as well as the sight of many trains passing per day. Noise levels would be significantly higher.

A fleet of 2700 tank trucks operating daily on the primary and secondary roads in Colorado, New Mexico, and West Texas would cause extreme congestion and noise in cities and towns along the route. Assuming an average fuel consumption of 4 miles per gallon of diesel oil, a consumption of more than 230,000 gallons of fuel per day would be required to transport the CO_2. Air emissions would approximate over 1000 pounds of sulfur oxides and 7500 pounds of nitrogen oxides per day along the truck route.

Other Main Pipeline Routes

The proposed route for the main CO_2 pipeline was chosen after considering a number of limiting factors.

The most direct route would involve the least amount of surface disturbance and the degree of overall impact to the environment would be held to the minimum.

Alternate routes to the east of the proposed route would pass through the extremely rugged San Juan Mountains and the Sangre de Cristo Range of the southern Rocky Mountains. The difficulties of construction and the environmental impact of such routes would be far greater than those of the proposed route.

Alternate routes to the south of the proposed route would cross an extensive area of known and potentially economic coal reserves. In addition, many recorded archaeological sites and nationally-designated archaeological monuments lie to the south of the CO_2 well field.

The Federal Land Policy and Management Act of 1976 directs the placement of proposed rights-of-way to existing corridors whenever possible. The proposed route follows existing pipeline rights-of-way for 91 percent of its length.

SPECIFIC ALTERNATIVES

Consideration was given to other possible development methods for the CO_2 well field and other uses of the CO_2 but no reasonable alternative to this part of the proposed action could be identified. The authorized officer (USGS) has abundant flexibility and discretion to determine well siting, gathering line location, and other well field operations for effective management on a case-by-case basis. Any appropriate alternatives suggested in the DES review process will be carefully considered.

No-Action Alternative

With the no-action alternative, neither drilling permits nor rights-of-way would be granted. Thus, the CO_2 well field would not be further developed and the pipeline would not be built. The existing exploratory well sites would be reclaimed to the satisfaction of the authorized officer. The impacts from CO_2 well field development and pipeline construction that are described in Chapter 3 would not occur. The CO_2 would remain available for other uses. The lands would continue to be in their present relatively undisturbed state and remain available for other multiple-use purposes under BLM management programs.

Impacts. The no-action alternative would not allow production of the additional 280 million barrels of oil from the Denver Unit of the Wasson Field. This would mean that about 1.6×10^{15} Btu that would be supplied by the oil would not be available. The no-action alternative would not allow extension of the production life of the Wasson Field by use of the CO_2 miscible process. This would result in the non-employment or the transfer of about 50 oil field employees from the area over the next 20 years. The impact of their loss or continuance of employment in the area, while personally important, would have no economic effect on state tax revenues. In addition, all impacts associated with the proposed project implementation would not occur.

Alternate Segments of Proposed Main CO_2 Pipeline Route

Three segments of the proposed main CO_2 pipeline route are considered feasible pipeline route alternatives and are presented in the following discussion.

1. <u>Alternative Segment A (Overall Length: 480 Miles; Alternate Segment Length: 200 miles)</u>

Alternate Segment A (Map 8-1) is the same as the proposed route until milepose (MP) 208. There Alternate Segment A heads north to parallel the existing MAPCO pipeline for 200 miles, then merges with the proposed route at MP 409. This alternate segment parallels and lies from 5 to 10 miles north of the proposed route. The existing environment crossed by Alternate Segment A is similar to that described for the proposed route with the two exceptions: (1) Alternate Segment A does not pass through Cibola National Forest; and (2) soil erosion along the right-of-way is estimated to be 141,000 tons.

<u>Impacts</u>. Impacts associated with Alternate Segment A are those discussed for the proposed route. The potential soil loss impact is slightly greater than that calculated for the main route (17,300 tons versus 15,400 tons). Alternate Segment A is 2 miles longer than the proposed route. Total impact to visual resources is expected to be reduced because Alternate Segment A only crosses 3 of the 5 Roadless Study Areas (VRM Class I) crossed by the proposed route.

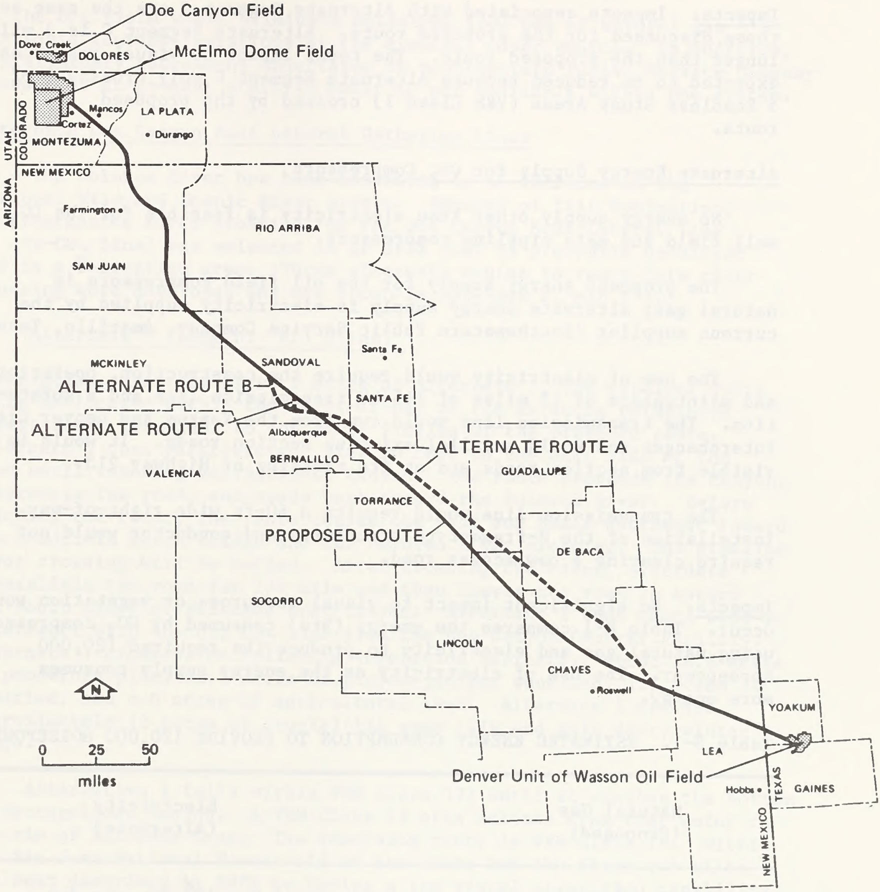
2. <u>Alternate Segment B (Overall Route Length: 480 Miles; Alternate Segment Length: 52 Miles)</u>

Alternate Segment B, as shown on Map 8-1, is the same as the proposed route until MP 160. There Alternate Segment B heads south, and parallels the existing Southern Union pipeline for about 23 miles. The segment then extends east for about 29 miles, lying to the south of the boundaries of the Zia and the Santa Ana Pueblo Indian Reservations. Alternate Segment B crosses the Rio Grande about 3 miles sought of the proposed river crossing and then intersects the proposed route at MP 210 and continues in the same alignment as the proposed route.

<u>Impacts</u>. Impacts associated with Alternate Segment B are the same as those discussed for the proposed route. Alternate Segment B is 2 miles longer than the proposed route. About 12 miles of Alternate Segment B would cross VRM Class IV area instead of VRM Class III crossed by the proposed route. The total impact to visual resources is expected to be reduced because Alternate Segment B only crosses 4 of the 5 Roadless Study Areas (VRM Class I) crossed by the proposed route.

3. <u>Alternate Segment C (Overall Length: 481 Miles; Alternate Segment Length: 20 Miles)</u>

Alternate Segment C (Map 8-1) is the same as the proposed route until MP 192. There Alternate Segment C heads south for 6 miles, lying between the eastern boundary of the Zia Indian Reservation and the western boundary of the Santa Ana Pueblo Indian Reservation. Alternate Segment C then extends southeast for 14 miles and crosses the Rio Grande about 3 miles south of the proposed route crossing. Alternate Segment C intersects the proposed route at MP 209 and continues in the same alingment as the proposed route.



Map 8-1. MAIN CO_2 PIPELINE ALTERNATE ROUTES

Impacts. Impacts associated with Alternate Segment C are the same as those discussed for the proposed route. Alternate Segment C is 3 miles longer than the proposed route. The total impact to visual resources is expected to be reduced because Alternate Segment C only crosses 4 of 5 Roadless Study Areas (VRM Class I) crossed by the proposed route.

Alternate Energy Supply for CO_2 Compressors

No energy supply other than electricity is feasible for the CO_2 well field and main pipeline compressors.

The proposed energy supply for the oil field compressors is natural gas; alternate energy supply is electricity supplied by the current supplier (Southwestern Public Service Company, Amarillo, Texas).

The use of electricity would require the construction, operation, and maintenance of 15 miles of 115-kV transmission line and a substation. The transmission line would run from the Yoakum and Denver City interchanges and would parallel existing section roads. It would be visible from section roads and at its crossing of Highway 213.

The transmission line would require a 60-ft wide right-of-way. Installation of the H-frame-type structures and conductor would not require clearing a new access road.

Impacts. No significant impact to visual resources or vegetation would occur. Table 8-1 compares the energy (Btu) consumed by CO_2 compressors using natural gas and electricity to produce the required 120,000 horsepower. The use of electricity as the energy supply consumes more energy.

Table 8-1. ESTIMATED ENERGY CONSUMPTION TO PROVIDE 120,000 HORSEPOWER

Natural Gas (Proposed)	Electricity (Alternate)
1.8×10^4 Btu per day	1.9×10^6 Btu per day
6.6×10^5 Btu per year	6.9×10^7 Btu per year
2.0×10^6 Btu per 30 years	2.1×10^8 Btu per 30 years

The 115-kV would be taken from the existing grid. The power plant source of the electricity is not known and would be quite distant from the point of use. The use of electricity to power compressors

at the oil field would eliminate emissions from use of natural gas but would increase emissions at the electric power source. In addition, a preliminary assessment undertaken by Southwestern Public Service Company shows that at present electric power is not available within the system.

Alternate Doe Canyon East Lateral Gathering Lines

The Dolores River has been nominated to be included in the National Wild and Scenic River system. Because of this nomination, an alternative river crossing for the Doe Canyon East Lateral line (a dry-CO_2 line) was selected in an area that is presently developed and is a recreation area. Three alternate routes to reach this river crossing were developed and are shown in Appendix F, Map F-12.

1. Alternate 1 (Length: 8.1 Miles)

Description. For the first 2 miles of Alternate 1, the pipeline route would be located within the right-of-way of the existing unimproved forest road, identical to the first 2 miles of the proposed route. Alternate 1 then parallels and lies 20 feet to the east side of the road until reaching Narraguinnep Canyon. The route descends the canyon, intersects the road, and heads west toward the Dolores River. Before reaching the river, the route leaves the road and heads southwest toward the Bradfield Ranch bridge and the Dolores River crossing. The pipeline river crossing will be buried. After crossing the river, Alternate 1 parallels the road for 1/4 mile and then leaves the road to ascend the south slope of Williams Draw Canyon. Alternate 1 then heads west to interesect with the dry CO_2 line from the Doe Canyon Central Facility. Alternate 1 crosses the following vegetation habitats: about 18.6 acres of ponderosa pine; 22.2 acres of pinyon-juniper woodland, 1.2 acres of riparian; and 6.6 acres of agricultural land. Alternate 1 crosses approximately 12 acres of crucial big game (elk and mule deer) winter range.

Alternative 1 falls within VRM Class III until it reaches the bottom of Narraguinnep Canyon. A VRM Class II area extends from that point to the rim of Williams Draw. The remaining route is VRM Class IV. Within the San Juan National Forest all of the route but the first 1.5 miles has been described by USFS as having a low visual absorption capability (See discussion of visual absorption capability in Appendix C.)

Construction Procedures. Conventional construction procedures for Alternate 1 are the same as for the proposed route. Only areas requiring special procedures are discussed here. As in the first 2 miles of the proposed route, special construction procedures would be necessary. The roadbed is almost solid rock which will require blasting and ripping to establish a pipe ditch. Rock from the ditch would have to be hauled off and compactible replacement material hauled in. Ditchline barriers would have to be installed and periodically inspected to minimize deterioration of the road due to erosion by water flowing underground

along the ditchline. Blasting or ripping the ditch would fracture the roadbed rock adjacent to the ditch. As continuing vehicular traffic further loosens the fractured rock, periodic repairs to the roadbed would be needed to maintain the road. Construction and maintenance equipment would utilize all available space on the road for work space thereby causing some temporary interruptions of vehicular traffic on the road.

Impacts. The impact of Alternate 1 while within the road would generally be limited to disruption of traffic and limited clearing on the pipe side of the road. When this route is not within the road, the right-of-way must be cleared. The construction of the section descending Narraguinnep Canyon may cause rock slides because of the loose rock on the canyon wall. The Dolores River would be affected during construction activities by increased downstream siltation.

The impact caused by the loss of the vegetation is minor because of the small amount affected (48.6 acres). The impact caused by the loss of crucial big game winter range is also expected to be minor. Significant impact to visual resources caused by construction of this alternative gathering line would occur where the pipeline (1) descends Narragunnep Canyon wall; (2) leaves the roadway to bypass a switchback; (3) crosses the Dolores River; and (4) ascends Williams Draw Canyon wall. The highest VRM class objective that can be met in those areas after construction is complete is VRM Class III. Revegetation and/or screening after construction would reduce the visual impact within 10 to 15 years. After that time the highest class objective that would be met in those areas would be VRM Class II, their current classification.

2. Alternate 2 (Length: 8.3 Miles)

Description. For the first 2 miles of Alternate 2, the pipeline would be located in the existing forest road and is identical in location as the first 2 miles of the proposed route. Alternate 2 continues within the road for an additional 2.5 miles to the north rim of Narraguinnep Canyon. Here the route descends the canyon, intersects the road, and then continues within the road. Before reaching the Dolores River, the route leaves the road to bypass a switchback. The route again lies within the road to cross the Dolores River at the Bradfield Ranch bridge. The pipeline river crossing would be buried. Alternate 2 continues within the road as it ascends Williams Draw. The route then heads south and west to intersect the dry-CO_2 line from the Doe Canyon West Central Facility.

Alternate 2 crosses the following vegetation habitats: about 18.6 acres of ponderosa pine; 30.6 acres of pinyon-juniper woodland; 1.2 acres of riparian; and 5.4 acres of agricultural land. Alternate 2 crosses 12 acres of crucial big game (elk and mule deer) winter range.

Alternate 2 falls within VRM Class III until it reaches the bottom of Narraguinnep Canyon. A VRM Class II area extends form that point to the rim of Williams Draw. The remainding route is VRM Class IV. Within the San Juan National Forest this route (except the first 1.5 miles) has been described by the USFS as having a low visual absorption capability.

Construction Procedures. Conventional construction procedures for Alternate 2 are the same as for the proposed route and Alternate 1. Special procedures would be required during construction to protect the telephone cable buried in the road along Williams Draw.

Impacts. The impact of Alternate 2 while within a road would generally be limited to disruption of traffic and limited clearing on the pipe side of a road. When this route is not within a road (switchback bypass and after ascending Williams Draw), the right-of-way must be cleared. The construction of the section descending Narraguinnep Canyon may cause rock slides because of the loose rock on the canyon wall. The Dolores River would be affected during construction activities by increased downstream siltation.

The impact caused by the loss of vegetation (49.8 acres) and crucial big game winter range is expected to be minor.

Significant impact to visual resources caused by construction of this alternative gathering line would occur where the pipeline (1) descends Narragunnep Canyon; (2) leaves the roadway to bypass a switchback; and (3) crosses the Dolores River. VRM Class III is the highest VRM Class objective that can be met in those areas after construction is complete. Revegetation and/or screening after construction would reduce the visual impact within 10 to 15 years. After that time the highest class objective that can be met in those areas is VRM Class II, their current classification.

3. Alternate 3 (Length: 12 Miles)

Description. Alternate 3 is identical to Alternate 2 except Alternate 3 follows within the numerous switchbacks of the existing unimproved forest road that descends Narraguinnep and Dolores River canyons.

Alternate 3 crosses the following vegetation habitats: about 18.6 acres of ponderosa pine; 46.8 acres of pinyon-juniper; 1.2 acres of riparian; and 5.4 acres of agricultural land. Alternate 3 crosses about 30 acres of crucial big game (elk and mule deer) winter range.

Alternate 3 falls within VRM Class III until it reaches the bottom of Narraguinnep Canyon. VRM Class II extends from that point to the rim of Williams Draw. The remaining route is VRM Class IV. Within the San Juan National Forest this route (except the first 1.5 miles) has been described by USFS as having a low visual absorption capability.

Construction Procedures. Construction procedures for Alternate 3 are the same as discussed for the proposed route and other alternatives.

Impacts. The impact of Alternate 3 while within the road would generally be limited to disruption of traffic and limited clearing on the pipe side of the road. When this route is not within the road (after ascending Williams Draw), the right-of-way must be cleared. With continuing vehicular traffic, loosened fractured rock in the switchback section for the road may cause rock slides. The Dolores River would be affected during construction activities by increased downstream siltation.

The impact caused by the loss of vegetation (53.4 acres) and crucial big game winter range (30 acres) is expected to be minor.

Construction of this alternative is not expected to have significant impact to visual resources except at the Dolores River crossing. VRM Class III is the highest VRM Class objective that can be met after construction is complete. Revegetation and/or screening at the Dolores River crossing after construction would reduce the visual impact within 10 to 15 years. After that time the highest class objective that can be met is VRM Class II, its current classifiation.

Alternative Construction Procedure for Alternate Doe Canyon East Lateral Gathering Line

An alternative construction procedure between points A, B and C along alternate dry CO_2 gathering lines I and II is above ground construction. Based upon terrain characteristics, the 1700 foot route has been divided into two sections, as shown on Map F-12. The 1300 foot section between the northern rim of Narraguinnep Canyon (Point A) and the canyon bottom (Point B) and the 400 foot reach of pipeline that runs parallel to and in the canyon location until intersecting the road (Point C). The section of pipeline between points A and B would traverse an approximate 50 percent slope (a drop of 640 vertical feet in 1300 horizontal feet). This extensive slope would require that the pipeline be secured to the slope in order to prevent pipe creep caused by the variance between day and night temperatures (expansion and contraction), and continual downward movement due to the extensive slope angle. The following general procedure would be followed in order to secure the pipe to the slope:

- A 25 foot right-of-way would have to be cleared for equipment and materials access.

- At presently undetermined intervals along the slope, concrete caissons on which the pipe would be attached would be placed in solid material. This would require removing unconsolidated surface materials, drilling and most likely blasting into rock for caisson foundation, and transporting caisson materials to each location.

- The pipe would have to be transported and attached to each caisson. This could be accomplished by (1) welding a string of pipe together on the road and pulling it down, (2) transporting individual joints to welding locations by side-boom tractor, or (3) by helicopter.

- Upon completion of caisson construction and pipe welding, the pipe would be attached to the caissons by a saddle and closing device.

The section of pipeline along Narraguinnep Canyon floor (between points B and C) would be constructed in a similar manner. The exception could be that caissons would not be as closely spaced as between A and B because of the relatively flat terrain.

Impacts. Between points A and B the 25 foot right-of-way would be cleared of most loose rubble and debris so crawler tractors transporting drills, compressors, concrete, and possibly pipe could traverse the steep slope safely. This would cause about 0.8 acres of pinyon-juniper woodland to be removed. At the caisson locations, a level bench would be excavated to facilitate drilling equipment and overall caisson construction. Pipeline construction between points B and C would require extensive modification to existing terrain and access would need to be provided. This would require the removal of some vegetation and right-of-way grading. The entire section of pipe (points A to B to C) would be exposed to damage from rupture and liability due to rockfalls, landslides, flooding, and vandalism. The effects of a release of CO_2 are discussed in Chapter 6.

The removal of vegetation required for the alternate construction method in Narraguinnep Canyon and the physical presence of the aboveground structure would have significant impact to visual resources. The highest VRM Class objective that can be expected to be met after construction with this procedure would be VRM Class IV. Revegetation and/or screening would reduce the impact in 10-15 years. After that time the structure would be less visible and the area can be expected to meet the VRM Class III objectives, its current classification.

Alternative Transmission Line Corridors

Electricity to drive the compressors at the CO_2 well field, along the main CO_2 pipeline, and, as an alternative, at the Denver Unit would be supplied by local utilities. The following transmission line routes are the only alternatives presented since the environmental impacts of other alternatives would be equal to or greater than the impacts for the proposed transmission line routes. Environmental impacts of transmission lines will be examined in a supplemental environmental assessment (EA) written for the individual rights-of-way actions.

1. Alternate Corridor 1

Transmission line Alternate Corridor 1 (about 1 mile wide) heads east and south for 7.7 miles from the existing Colorado-Ute 115-kV line to the proposed Doe Canyon East Central Facility, as shown on Map F-13. Alternate Corridor 1 includes the following vegetation habitats: about 6.7 miles of ponderosa pine; and 1.0 mile of pinyon-juniper woodland. Alternate Corridor 1 does not contain any crucial big game (elk and mule deer) winter range.

The entire corridor passes over rolling timber land managed as VRM Class IV by the BLM.

Construction Procedures. Construction procedures for Alternate Corridor 1 are the same as those for the proposed corridor.

Impact. The impact of constructing a transmission line within Alternate Corridor 1 would be insignificant because (1) vegetation would not be cleared along the right-of-way and (2) the corridor is within VRM Class IV.

2. Alternate Corridor 2

Transmission line Alternate Corridor 2 (about 1 mile wide) heads east from the proposed 115-kV transmission line for the Doe Canyon West Central Facility for approximately 7.5 miles to the Doe Canyon East Central Facility, as shown on Map F-13. The corridor crosses the Dolores River about 2.7 miles east of the proposed line. After crossing the river the corridor is within the San Juan National Forest.

Alternate Corridor 2 includes the following vegetation habitats: 2.0 miles of ponderosa pine; 1.2 miles of pinyon-juniper woodland; 0.1 miles of riparian; and 2.0 miles of agricultural land. Alternate Corridor 2 does not contain any crucial big game (elk and mule deer) winter range.

Alternate Corridor 2 from the existing line to the western edge of Dolores Canyon is managed by the BLM as VRM Class IV. Within the canyon the western side of the Dolores Canyon and the Dolores River are managed by the BLM as Class II areas in which management actions should not remain evident on the landscape. The eastern side of the Dolores Canyon and portions of Doe Canyon are determined by the USFS to have a low visual absorption capacity. The remainder of Doe Canyon is determined to have a moderate absorption capacity. The mesa extending to the east of Dolores and Doe canyons is managed as VRM Class IV.

Construction Procedures. Construction procedures for Alternate Corridor 2 are the same as those for the proposed corridor.

Impact. The impact of constructing a transmission line within Alternate Corridor 2 would be insignificant except for visual resources within the canyons and at the river crossing. Within the canyons and at the Dolores River crossing, the line would constitute a significant visual impact because it exceeds both the BLM and USFS impact limits estalished for the area.

3. Alternate Corridor 3

Transmission line Alternate Corridor 3 (about 1 mile wide) parallels the proposed dry-CO_2 gathering line route from the Doe Canyon East Central Facility, as shown on Map F-13. Alternate Corridor 3 begins at the proposed 115-kV transmission line for the Doe Canyon West Central Facility and heads east across the Dolores River, and then heads northeast to the Doe Canyon East Central Facility.

Alternate Corridor 3 includes the following vegetation habitats: 2.0 miles of ponderosa pine; 3.3 miles of pinyon-juniper woodland; 0.2 miles of riparian; and 2.0 miles of agricultural land. The corridor contains about 3.0 miles of crucial big game (elk and mule deer) winter range.

Within the Dolores Canyon, the BLM manages the land as a VRM Class II area where management actions should not remain evident on the landscape. The USFS has determined the eastern portion of the canyon area to have moderate visual absorption capacity. On the mesa lands which extend to the east of the Dolores Canyon, the proposed line route traverses Class III and Class IV areas. From the mesa edge to the point where the line joins the roadway, the land is managed as Class IV. Along the roadway, the land is managed as a Class III.

Construction Procedures. Construction procedures for Alternate 3 are the same as those for the proposed corridor.

Impact. Within the Class III and Class IV areas, the impact of a line would not be significant. However, within the Class II areas in the canyon and at the Dolores River crossing, a line would not meet the objectives of a Class II VRM.

Alternative Methods of Transmission Line Construction

By this alternative, the 115-kV electric transmission lines would be constructed using helicopters to transport poles, insulators, wire, and associated equipment. No heavy construction equipment would be used in the right-of-way. Construction of anchor holes, anchor bolts, and guy wires would be by portable machinery (augers and compressors) and hand tools. Wire would be layed using the helicopter and pulled using ground crews, tensioners, and pullers. Impacts of this alternative would be associated with a large staging area for poles, equipment, fuel trucks,

and helicpoter landing pad near the construction site. The right-of-way would have no access except by foot in case of repair or maintenance need. Areas of extreme visual sensitivity would benefit by minimum disturbance. Areas of extreme soil erosion hazard would benefit from minimum disturbance to the surface. The helicopter would increase noise levels during the construction period. Since on-ground methods are labor intensive, the alternative would require a larger work force containing extra workers using a larger work force. The alternative is subject to the availability of helicopters of the size necessary to complete the work. Weather conditions would have a greater effect on construction schedules.

Alternate Access Roads to Doe Canyon Field

Road access to the Doe Canyon Field is by use of three access routes. The proposed route, the Dolores River Canyon Road and the Forest Service road heading northeast from the Bradfield Ranch bridge, may not be maintained, particularly at the specifications required, when construction of the McPhee Reservoir Dam begins. Alternate access roads to the Doe Canyon Section are therefore presented below and shown on Map F-13.

Alternate Access Road 1. Alternate 1 would use the Bradfield Ranch Road from Highway 666 across the Dolores River at the Bradfield Ranch bridge. This alternative would be used only for light traffic (to 20 tons) because the bridge is not rated for heavy traffic. Since the bridge limits access by heavy loads, this road is not considered reasonably available for use by heavy trucks (greater than 20 tons).

Alternative Access Road 2. Alternate 2 would use existing roads through the San Juan National Forest from the east. The existing road enters from the Dolores Road near the Willow Spring Guard Station (Map F-13). The road runs west approximately 9 miles to a junction near Kappenhafer Reservoir. From there it runs northwest approximately 6 miles to Narraguinnep Spring. The road would be upgraded at this point for approximately 2 miles west to the developed road in Near Draw. From that point the road runs north for 2 miles and west for 2 miles to the Bradfield Ranch Road, the main access to the Doe Canyon Field.

The upgraded portion of the access road would be constructed to 40-ton, all-weather standards, as determined by USFS stipulations. The remainder of the access route is presently used by logging trucks which average 40 tons when loaded.

The road would be treated with water at regular intervals during the dry season to limit particulate pollution from dust. Design criteria of culvert placement and road-base material thickness would minimize surface deterioration during wet periods. If surface

deterioration became a problem, the road would be maintained with additional surface material and grading. In extreme weather conditions, access would be limited or halted to prevent serious deterioration of the road surface.

Surfacing material for the access road would be obtained through private sources or use permits from the surface management agencies.

Impacts. Impacts of this alternate access road for the short term (3 years) and long term (30 years) would be as follows: There would be some unavoidable production of dust pollution over the short term; however, water sprinkling would lower this to below those amounts produced by existing commercial traffic. Upgrading and reconstruction would cause some unquantifiable amount of soil erosion until revegetation and other mitigation measures became effective. The amount of erosion compared with existing conditions would not be significant. These impacts would not occur with the proposed access route since the proposed route would not require any new road construction.

Access by heavy trucks and more frequent lighter service vehicles would detract from the recreational experience of visitors. However, since the roads are presently used by logging trucks, the occasional passage of vehicles related to the proposed project would not cause a significant decrease in recreational attraction of the area.

CHAPTER 9

CONSULTATION AND COORDINATION

A preliminary draft environmental report (PDER) was prepared for the applicant by Woodward-Clyde Consultants (WCC). A Department of Interior interdisciplinary team used the PDER as the basis for the BLM draft environmental statement (DES). This team provided guidance, assistance, and specific direction to WCC in preparation of the DES. The team exercised full control over the contents of the DES and provided direct input to the document.

The scope of the proposal has necessitated a concerted coordination effort with various federal, state and local agencies. Coordination with federal agencies included Department of Interior (DOI), Bureau of Indian Affairs (BIA), U.S. Geological Survey (USGS), National Park Service (NPS), and U.S. Forest Service (USFS). These agencies were advised of the proposal and provided input to the companies in developing this proposal. In addition, presentations were made at meetings with Indian tribes, to inform them of the proposal and determine if any modification were necessary. Shell conducted project presentations to the Navajo Indian Tribe, Southern Ute Tribe, Ute Mountain Tribe, Albuquerque BIA, Washington Office (W.O.). Bureau of Mines, W.O. Bureau of Reclamation, W.O. Corps of Engineers, San Juan National Forest Office, Cibola National Forest Office, W.O. USFS, Durango USGS, Albuquerque USGS, Roswell USGS, W.O. Interstate Commerce Commission, W.O. National Park Service, State of Colorado, State Historical Preservation Officer, Santa Ana Pueblo Tribal Council, and the Zia Tribal Council.

Consultation and Coordination in Preparation of the Draft Environmental Statement

During preparation of this draft environmental statement, federal, state, and local agencies and representatives of private industry were consulted. Individuals and groups with special expertise or interest relating to the proposed action provided information and in some cases, additional data. Notification to the public of the preparation of the ES was made in the Advisor, a monthly news bulletin prepared by the BLM New Mexico State Office. Distribution includes the media, local and state governmental agencies, users of public lands, special interest groups, and some of the general public.

A request is to be submitted to the U.S. Fish and Wildlife Service (FWS) for formal consultation under Section 7 of the Endangered Species Act of 1973 to ensure that the proposed project would not adversely affect any of the endangered or threatened species that may be present in the vicinity of the proposed project (black-footed ferret, bald eagle, peregrine falcon, whooping crane, Colorado River squawfish, and Pecos gambusia).

The nature of the contact with Bruce Rippetau, State Historic Preservation Office (SHPO), Colorado was for project presentation and as a source of information on archaeological resources and procedures. This same type of meeting was held with Tom Merlin, SHPO, New Mexico.

Procedural information was requested from the Texas State Historical Commission which is the state agency responsible for SHPO activity in Texas.

Bruce Rippetau, Tom Merlin, and Truett Latimer, State Historic Preservation Officers for Colorado, New Mexico, and Texas have been notified of the project and the ES. Before the Final ES is filed, the BLM will enter into formal consultation with the State Historic Preservation Officers of the three respective states under the applicable portions of 36 CFR 63, 36 CFR 800 and the Memoranda of Agreement with the SHPOs of Colorado, New Mexico, and Texas.

The USFS was contacted at several levels. District, Forest, and Regional Office staffs were consulted for input to the development of the Draft ES.

The USGS provided technical expertise in the fields of hydrology and geology at the request of the BLM. The USGS also reviewed and submitted comments on the ES during its development.

Table 9-1 provides a summary of major contacts, the nature of the contact, and the type and extent of input to the development of the ES.

Table 9-1. CONSULTATION AND COORDINATION

Contact	Nature of Contact	Type and Extent of Input
FEDERAL AGENCIES		
Bureau of Indian Affairs	Project presentation, coordination	Tribal procedures, requirements, and archaeological resource information
Bureau of Mines	Project presentation, coordination	
Bureau of Reclamation	Project presentation, coordination. Requested interrelationship information	Supplied input on Dolores River Project and Paradox Valley Project, regional hydrologic data, phreatophyte control information
Corps of Engineers	Requested information on requirements regarding licensing	Supplied information on permit and licensing and stream crossing requirements.
Fish and Wildlife Service	Requested biological data	Furnished data availability including reptile studies
Forest Service	Requested coordination and interrelationship information	Supplied information on San Juan and Cibola National Forest requirements, procedures and planning data. Wildlife data availability, restricted use area, archaeological data. Review of PDER
Geological Survey	Requested Technical Expertise	Furnished Hydrologic and geologic specialists, drilling program data, aerial photo and map coverage, exploration data and procedural information. Review of PDER
Interstate Commerce Commission	Project presentation	Furnished agency ES requirements
National Park Service	Requested procedures	Supplied archaeological data and floristics information, procedural information

Table 9-1. (continued)

Contact	Nature of Contact	Type and Extent of Input
Soil Conservation Service	Requested resource data	Supplied soils, biological (flora, fauna) data, mapping, land use mapping
STATE AGENCIES Colorado		
Air Pollution Control District	Project coordination	Furnished air quality guidelines, suitability of WCC monitoring program
Program of Health Air Pollution Control Division	Requested agency procedures	Supplied information ,i.e., construction, fugitive dust permits, procedural requirements
Department of Revenue	Requested tax information	Supplied county tax data
Department of Water Resources	Project coordination	Supplied drainage basin plans
Division of Planning	Requested planning data	Supplied statistical data and projections
Division of Wildlife	Requested wildlife data	Supplied fish and wildlife data, biological mapping, wildlife maps
Oil and Gas Conservation Commission	Project presentation	Furnished well pad reclamation procedural information
San Juan Basin Regional Planning Commission	Project coordination	Provided overview on land management in southwestern Colorado
State Cartographer	Requested maps	Supplied state of Colorado aerial and map coverage
State Forest Service	Requested forestry maps	Supplied state of Colorado aerial and map coverage (flora and fauna)

Table 9-1. (continued)

Contacts	Nature of Contact	Type and Extent of Input
State Historic Preservation Office	Project coordination	Supplied archaeological resource and procedural information
State University Extension Division Agricultural Services	Requested resource data	Supplied agricultural data
New Mexico		
Department of Finance and Administration	Requested statistical data	Supplied public school statistics and tax info
Department of Games and Fish	Requested data availability	Supplied biological, endangered species, aquatic biologic and wildlife data, data availability
Department of Transportation	Requested rights-of-way procedural information	Supplied procedural information on rights-of-way
Deptartment of Transportation	Requested traffic data	Supplied traffic counts
Environmental Improvement Division	Requested data and procedural information	Supplied biologic data availability, water quality data, agency requirements and permit and licensing requirements
McKinley Area Council of Governments	Project presentation	Furnished Council of Governments plans
Museum of New Mexico	Requested procedural and resource information	Supplied archaeological data and procedural information
San Juan Regional Planning Commission	Project coordination	Furnished Commission plans
Southeastern Economic Development District	Project coordination	Furnished District plans
Southern Rio Grande Council of Governments	Project coordination	Furnished Council of Governments plans

Table 9-1. (continued)

Contact	Nature of Contact	Type and Extent of Input
State Archaeologist	Requested procedural and resource information	Supplied archaeological data and procedural information
State Historic Preservation Office	Project coordination	Furnished archaeological resource and procedural information
State Land Office	Requested permit information	Supplied permit and licensing requirements
State Planning Office	Requested planning information	Supplied transmission corridor data and critical area studies
Texas		
Air Control Board	Requested procedural information	Supplied permit and licensing requirements
Department of Water Resources	Requested procedural information	Supplied permit and licensing requirements
General Land Office	Requested procedural information	Supplied permit and licensing requirements
Permian Basin Council of Governments	Project coordination	Furnished Council of Governments plans
South Plains Association of Governments	Project coordination	Furnished Association of Governments plans
State Employment Commission	Requested statistical data	Supplied employment data
State Historical Commission	Requested procedural information	Suppied permit and licensing requirements
State Railroad Commission	Requested procedural information	Supplied permit and licensing requirements

Table 9-1. (continued)

Contact	Nature of Contact	Type and Extent of Input
Local Agencies Colorado		
City of Cortez, City Manager	Requested planning information	Supplied city planning practices
Dolores County Assessor	Requested statistical data	Supplied county tax data
Montelores Planning Commission	Project coordination	Furnished commission planning practices
New Mexico		
McKinley County Planning Dept.	Requested county plans	Supplied county plans
Texas		
Gaines County Tax Assessor	Requested statistical data	Supplied county tax data
Tribal Contacts		
Navajo	Project presentation	Furnished tribal requirements
Southern Utes	Project presentation	Furnished tribal planning procedures and requirements
Ute Mountain Utes	Project presentation	Furnished tribal planning procedures and requirements
Santa Ana Pueblo	Requested presentation	Furnished tribal planning procedures
Zia Pueblo	Project presentation	Furnished tribal planning procedures

Table 9-1. (concluded)

Contact	Nature of Contact	Type and Extent of Input
Other		
San Jose State University	Requested technical data	Supplied archaeological and biological data
Colorado River Tours	Requested use data	Supplied Dolores River tour data
Colorado State Univ. San Jose Basin Archaeological Research Station	Requested technical data	Supplied access to station to install and monitor meteorological tower
Fort Lewis College	Requested technical data availability	Supplied wildlife data availability
University of Colorado	Requested technological expertise	Supplied archaeological consultation and Colorado biological mapping
University of Denver	Requested, statistical information	Supplied statistical abstracts
New Mexico State University	Requested technical expertise	Supplied archaeological consultant
Sandia Labs	Requested technical data	Supplied ES biological data
San Juan Bird Watchers	Requested technical information	Supplied avifauna data availability
University of New Mexico	Requested maps	Supplied land use and vegetation mapping for Colorado and New Mexico

GLOSSARY

AF - acre-foot. Volume of liquid required to cover one acre to a depth of one foot

air quality standard - any state or national ambient air quality standard (NAAQS), as specified ambient concentration for a specified air pollutant not to be equalled or exceeded more than once per year. Each standard is based on measurements averaged over a given time period.

air quality standards, primary - national primary standards meant to protect the health of most people with a margin of safety

air quality standards, secondary - national secondary standards meant to protect property and other human welfare values, including aesthetics

ambient - encompassing atmosphere or body of water

AMP - allotment management plan. Prescribes some form of pasture-rotation grazing system, along with necessary range improvement on grazing allotments (geographic units) of public lands

anaerobic - living, active, or occurring in the absence of free oxygen

anode - positive electrode of a cathodic protection system designed to inhibit external corrosion on buried structures such as pipelines. The anode is buried at a position in the earth located to distribute electric current from the anode through the soil and into the structure being protected.

API - American Petroleum Institute

AQCR - Air Quality Control Region. The United States is divided into AQCRs for designating jurisdictional boundaries in measuring and maintaining air quality.

aquifer - a subsurface rock interval that will produce water. Many oil reservoirs are underlaid or surrounded by an aquifer.

arroyo - a stream channel or gully, usually with steep banks, dry much of the time

AUM - animal unit month. A measure of forage or feed requirement to maintain one animal for 30 days.

average - as a measure, the sum of measurements divided by the number of measurements

average, one-hour - the average for measurements made in a one-hour period. Other averages for three hours, twenty-four hours, and one year are used in air quality monitoring.

backfill - earth that is replaced after a construction excavation

backhoe - a self-propelled machine, equipped with a toothed shovel, that scoops earth as the shovel is pulled toward the machine

bajada - a broad alluvial slope extending from the base of a mountain range into a basin. Formed by coalescence of separate alluvial fans.

barrel - a unit of volume measure for crude oil and liquid products equal to 42 U.S. gallons

baseline - air quality, water quality, or meteorological data used as a starting point in estimating the impacts of new emissions

biomass - the amount of living matter as a unit area of volume of habitat

biota - all of the species of plants and animals within a certain area or region

BLM - Bureau of Land Management, U.S. Department of Interior

block valve - a valve which can be closed to isolate one section of pipe from the adjacent section

board-foot - a standard measurement of timber products. A board-foot is a piece of wood one inch thick, twelve inches by twelve

BOD - biological oxygen demand

Btu - British thermal unit. A measurement of energy derived from burning hydrocarbon fuels.

carnivore - flesh-eating animal

cathodic protection - an anti-corrosion technique for metal installations in pipelines, tanks, and buildings in which weak electric currents are established to offset the current associated with metal corrosion

cathodic protection rectifier - the rectifier converts alternating current power supply into direct current output. This output is connected to a buried anode which produces an electrical current through the soil and into the pipeline, which is thus placed under cathodic protection.

cfm - cubic feet per minute

cfs - cubic feet per second

cf/yr - cubic feet per year. Applied as a measurement of natural gas.

check valve - a valve with a free-swinging tongue or clapper that permits liquid to flow in one direction only, as in a pipeline

climax - a type of plant or animal community which is in a relatively stable equilibrium with existing natural environmental conditions

CO_2 - carbon dioxide

coating and wrapping - a field operation for preparing a pipeline to be lowered into the ditch. The line is coated with an inert material, then spiral wrapped with a tough, chemically impregnated paper. Machines ride the pipe, and coat and wrap in one continuous operation. This process protects the pipeline from corrosion. For large pipeline jobs the pipe may be coated and wrapped at a mill or construction yard site, and any breaks in the coating corrected when the pipe is installed.

concentration - the relative content of a component (as dissolved or dispersed material). Measured by weight or volume of material per unit of volume of the medium

commercial forests - land growing stands of forest trees which possess present or potential merchantable value

cencentration, average - the average of a series of measurements of concentration

conventional recovery - primary or secondary recovery

critical viewpoint - the point(s) commonly in use where the view of management activity is the most disclosing

cultural modification - any human caused change which creates a visual contrast in the basic elements (form, line, color, texture) of the landscape

cultural resources - all evidence of past human expression on the environment

diffusion model - a model, calculated by formula, graphs, or computer, which estimates the dilution of an air pollutant as it is carried downwind. The models are based on physical principles with various simplifications to aid solvability.

dominant elements - the basic elements (form, line, color, texture) which exert the greatest influence on the visual character of the landscape

enhanced oil recovery (EOR) - recovery of oil from a petroleum reservoir resulting from application of an enhanced recovery process

enhanced recovery process - a known technique for recovering additional oil from a petroleum reservoir beyond that economically recoverable by conventional primary and secondary recovery methods. Three such processes are thermal recovery, miscible flooding, and chemical flooding.

emission - unwanted substances released by human activity into air or water

emission, primary - an emission which is treated as inert

emission, secondary - unwanted substances which are chemical by-products of emissions

fault - a fracture or zone of fractures in rock strata which have undergone movement that displaces the sides relative to each other, usually in a direction parallel to the fracture. Abrupt movement on faults is a cause of most earthquakes.

fauna - animals or animal life

flange - a type of pipe coupling made in two halves. Each half is screwed or welded to a length of pipe and the two halves are then bolted together joining the two lengths of pipe.

flora - plants or plant life

FLPMA - Federal Land Policy and Management Act of 1976. Provides for the management, protection, development, and enhancement of public lands. Also establishes guidelines for its administration.

front - inclimatology, the boundary between two dissimilar air masses

fugitive dust - airborne pulverized soil particles

gm - gram

gpm - gallons per minute

grusen - depressed crystal block bounded by faults on its long sides

harmony - a state of agreement or proportional arrangement of form, line, color and texture

herbivore - plant-eating animal

hydrostatic testing - filling a pipeline or tank with water under pressure to test for tensile strength; its ability to hold pressure without rupturing

ID - inside diameter of pipe. Used in specifying pipe size.

inhibitor - a chemical used to inhibit or retard internal corrosion of pipelines

intrusion - a feature (land or water form, vegetation or structure) which is generally considered out of context because of excessive contrast with the characteristic landscape

Jtu - Jackson turbidity unit. A measure of "muddiness" in water.

landscape character - the arrangement of a particular landscape by the variety and intensity of landscape features

mesa - a flat-topped hill or mountain bounded on at least one side by a steep cliff or slope

mg/l - milligrams per liter

microgram - one millionth of a gram

miscible - refers to mixing between two fluids with a resulting lack of interfaces

mitigation measures - methods or procedures established to reduce or eliminate the impact of human activities on the environment

monitoring station - a mobile or fixed site equipped to measure instantaneous or average ambient air pollutant concentrations

moraine - accumulation of rock material by a glacier. Occurs in various topographic forms, according to the manner of formation.

MP - mile post

NAAQS - National Ambient Air Quality Standard(s). Nationally specified ambient concentrations for various air pollutants not to be exceeded more than once a year. Each standard is specified for a given time period.

nitrate - any compound containing a subgroup of one nitrogen and three oxygen atoms. In atmospheres, a principal source is nitrogen dioxide.

nitric oxide - a molecule of one nitrogen and one oxygen atom - NO. Results usually from combustion of organic substances containing nitrogen and from recombination of nitrogen decomposed in air during high temperature combustion.

nitrogen dioxide - a molecule of one nitrogen and two oxygen atoms - NO_2. Results usually from further oxidation of nitric oxide (NO) in the atmosphere.

NO - nitric oxide

noise level, median - the level of noise exceeded fifty percent of the time. Usually specified as either the daytime or the nighttime median noise level.

NOx - oxides of nitrogen, a mixture of NO and NO_2

NO_2 - nitrogen dioxide

ORV - off-road vehicle. Maintenance or recreational vehicle disturbing natural habitat where no visible roadway exists.

OSHA - Occupational Safety and Health Administration (Federal)

oxidant - a mixture of chemically oxidizing compounds formed from ultraviolet stimulated reactions in atmospheres

oxides of nitrogen - a gaseous mixture of nitric oxide (NO) and nitrogen dioxide (NO_2) and symbolically represented as NOx. Can include particulate species such as nitrate compounds ($-NO_3$).

oxides of sulfur - a gaseous mixture of sulfur dioxide (SO_2) and sulfur trioxide (SO_3) and symbolically represented as SOx. Can include particulate species such as sulfate compounds ($-SO_4$).

ozone - a molecule of three oxygen atoms - O_3. A principle component of "oxidant" in photochemically polluted atmospheres.

particulate matter - pulverized matter or droplets, typically averaging one micron or smaller in diameter. Also called aerosol.

permeability - an index of the ability of reservoir rock to transmit fluids under the influence of a pressure gradient

pig (scraper) - a cylindrical device (3 to 7 feet long) inserted in a pipeline for the purpose of sweeping the line clean of water, rust, or other foreign matter. When inserted in the line at a "scraper trap," the pressure of the oil stream behind it pushes the pig along the line. Pigs or scrapers are made with tough, pliable discs that fit the internal diameter of the pipe, thus forming a tight seal as they move along cleaning the pipe walls.

pipeline patrol - the inspection of a pipeline for leaks, washouts, and other unusual conditions by the use of light, low-flying aircraft or land

polymer - a type of organic chemical, characterized by large molecules, that is added to water for polymer flooding

pore space - a small hole in reservoir rock which contains fluid or fluids. A fist-sized volume of reservoir rock may contain up to millions of interconnected pore spaces.

pore volume - total volume of all pores and fractures in a reservoir or part of a reservoir

porosity - ratio of pore volume and fracture volume to total volume in reservoir rock, usually expressed as a percent

ppb - parts per billion. A measure of concentration in liquids or gases.

ppm - parts per million

ppt - parts per thousand

psi - pounds per square inch

psig - pounds per square inch gauge (as observed on a gauge)

right-of-way (ROW) - (1) a legal right of passage over another person's land. (2) A strip of land for which permission has been granted to build a pipeline and for normal maintenance thereafter.

riparian - relating to or living on the bank of a river or stream

saturation - ratio of volume of pore fluid to pore volume, expressed as percent and usually applied to water, oil or gas separately. Sum of the saturations of each fluid in a pore volume is 100 percent.

scenario - an account or synopsis of a projected course of action or events

scraper trap - a facility on a pipeline for inserting and retrieving a scraper or "pig." The trap is essentially a "breech-loading" tube isolated from the pipeline by valves. The scraper is loaded into the tube like a shell into a shotgun. A hinged plug is closed behind it, and line pressure is then admitted to the tube behind the scraper. A valve is opened ahead of the scraper and it is pushed into the line and moved along by the oil pressure.

slug - a quantity of fluid injected into a well during enhanced oil recovery

SO_2 - sulfur dioxide

sour crude oil - crude oil with a relatively high sulfur content

spread - a group of construction personnel and equipment assembled to do a major construction job. The men and equipment are strung out along the right-of-way.

stringing pipe - placing joints of pipe end-to-end along a pipeline right-of-way in preparation for welding the joints together to form a pipeline

subsidence - (1) generally a gradual settling or sinking of the ground surface usually with little or no horizontal displacement. (2) The process of an air mass descending and resulting in heating by compression.

sweet crude oil - crude oil with a relatively low sulfur content

TDS - total dissolved solids

terrestrial - related to or living on land

TSP - total suspended particulates. The concentration (by weight) of all wet and dry particles suspended in the atmosphere.

Ug/M_3 - Millionths of a gram per cubic meter, a unit of concentration in liquids or gases

USLE - Universal Soil Loss Equation. A method of estimating soil loss from sheet and rill erosion as a function of rainfall intensity, soil erodibility, length and percent slope, vegetative protection, and erosion control practices.

vertebrates - animals with spinal columns and skulls. Includes fish, amphibians, reptiles, birds, and mammals

visual contrast rating - Bureau of Land Management's system for evaluating how well a project visually "fits" into a natural environment based on form, line, color, and texture

VRM - Visual Resource Management

visual sensitivity - consideration of people's uses of various environments and their concerns for maintenance of scenic quality and open-space values. Examples of areas of high visual sensitivity would be areas visible from scenic highways, wilderness areas, parks, recreational water bodies, etc.

wind rose - in air quality analysis, a 360° circle broken into sixteen equal quadrants for analyzing meteorological data

workover - a maintenance job on a well to improve its performance

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APPENDIX A

AIR QUALITY

This appendix contains a more detailed description of the methodology and assumptions used in emission calculations and modeling. Appendic A-1 contains a description of the emission factors used to calculate construction and operation emissions. Appendix A-2 contains a description of the method used to calculate construction and operation emissions. Appendix A-3 contains a description of the models and modeling assumptions used to estimate air quality effects for the CO_2 well field region. Appendix A-4 contains a description of the modeling assumptions used to estimate effects for the oil well field.

APPENDIX A-1

EMISSION FACTORS

For construction areas, an emission factor of 1.2 tons per acre per month has been published by the Environmental Protection Agency (EPA) (1975) for conditions similar to those in the project region. For wind erosion, an emission factor of 0.07 tons per acre per month was used. This factor was estimated from results derived by Gillette (1974) for atmospheric loading of suspended particles due to duststorms, and was then adjusted for wind and soil characteristics found in the project region.

At the present time there are no emission factors specifically applicable to pipeline digging operations. An estimate of the amount of particulates that might be generated can be obtained using emission factors derived for storage pile operations. The emissions are proportional to the volume of soil put through the removal, storage, and backfilling cycle, at 0.22 pound of particulate emitted per ton cycled (Cowherd et al., 1976).

The fugitive dust emissions for vehicular travel on unpaved roads were estimated using the following expression published by the EPA (1975):

$$E = 0.6\ (0.815)\ (V/30)\ \frac{(365 - w)}{365}$$

Where

E = the total suspended particulate emission factor
S = the silt content of the road surface soil (percent)
v = the average vehicle speed (miles per hour)
W = the mean annual number of days with 0.01 inch or more of rain

0.6 = a factor incorporated into the original expression to give the emission of only those particles smaller than 30 mm in diameter; namely, the amount of particulate emissions which may remain indefinitely suspended

Gaseous emissions from the construction fleet were calculated using emission factors for heavy and light duty construction vehicles and equipment. These factors have been published by the EPA (1975) in Compilation of Air Pollutant Emission Factors (publication AP-42), Tables 3.2.7-1. and 3.2.7-2.

Gaseous emissions due to the operational phase were also estimated using emission factors presented in AP-42. Emission factors for the fuel-fired facilities in the CO_2 well field came from Table 1.3-1. It was assumed that the fuel used would be 0.5 percent-sulfur distillate fuel oil. Factors for the natural gas-fired internal combustion compressors in the oil field came from table 3.3.2-1 of AP-42. However, it was assumed that the proposed New Source Performance Standard for internal combustion engines (maximum concentration in the stack of 700 ppm for nitrogen oxides) would be met. The compressors were assumed to burn low sulfur content natural gas. Particulate emissions are assumed to be negligible.

APPENDIX A-2

EMISSION ESTIMATES

Construction emissions were computed from previously derived emission factors and available construction data. For fugitive dust emissions, only 50 percent of any given construction area was assumed to be active at any one time. For road construction, 3 miles of road was assumed to be actively worked at any one time. The assumed pipeline burial rate was 5000 feet per day; this figure was obtained from an environmental impact assessment done for Sohio Transportation Company (Williams Brothers 1976).

These assumptions were used to convert the emission factors into mass of duty emitted per unit active time, which was then multiplied by the estimated time of construction. Construction crews were assumed to work 6 days per week, 10 hours per day. Fugitive dust emissions estimated for each phase of construction are given in Table A-1.

Gaseous emissions for all construction activities except pipeline laying were calculated by multiplying the emission factors (in pounds of pollutant per hour) by the estimated time of usage for each piece of equipment in the construction fleet. It was assumed that any one piece of equipment was active for only half the working period and that construction took place 6 days per week, 10 hours per day.

Table A-1. FUGITIVE DUST EMISSIONS FOR A WORST CASE YEAR

Source	Location	Emission Type	Emission (Tons/Yr)
Well Facilities	CO_2 Well Field	Construction Erosion	10.7 80.0
Central Facilities	CO_2 Well Field	Construction	129.6
Small Pipeline	CO_2 Well Field	Construction Burial	51.4 23.3
Access Roads	CO_2 Well Field	Construction Erosion	29.2 178.9
Origon Station	CO_2 Well Field	Construction	6.5
Vehicles @ 30 mph	CO_2 Well Field	Construction	10.8
Total			520.4
Main Pipeline	Main Pipeline	Construction Burial	226.9 103.0
Pipeline Compressor Station	Main Pipeline	Construction	25.9
Communication Stations	Main Pipeline	Construction	23.8
Maintenance Facility	Main Pipeline	Construction	16.2
Vehicles @ 30 mph	Main Pipeline	Construction	27.0
Total			422.8
Well Facilities	Oil Field	Construction Erosion	9.2 80.0
Booster Compressor Stations	Oil Field	Construction	32.4
Gas Treatment Plant	Oil Field	Construction	187.4
Flow Lines	Oil Field	Construction Burial	3.8 1.7
Vehicles @ 30 mph	Oil Field	Construction	10.8
Total			325.3

For pipeline laying activities, gaseous emission factors (in pounds of pollutant per thousand gallons of fuel consumed) were multiplied by estimated fuel usage. Fuel usage was estimated from data presented in the Sohio report for pipeline construction under conditions and terrain similar to those of the main CO_2 pipeline. Gaseous emissions for a worst case construction year are given in Table A-2.

Gaseous emissions due to the operational phase were calculated by multiplying the emission factors, in pounds of pollutant per thousand gallons of fuel used, by estimated fuel use figures. The facilities in the CO_2 well field were assumed to operate 24 hours per day, 365 days per year; estimated emissions are presented in Table A-3. The compressors in the oil field were assumed to run continuously at the maximum horsepower that might be required (20 compressors at 6000 horsepower each = 120,000 horsepower total). The compressors were assumed to be natural gas-fired internal combustion engines, as they would emit more than another alternative, gas-fired turbines. Emission factors described in Appendix A-1 were used to calculate the emissions tabulated in Table 3-3. The stack data required to calculate nitrogen oxide emissions are given in Table A-4.

APPENDIX A-3

CO_2 WELL FIELD MODELING OF POLLUTANT CONCENTRATIONS

Annual and 24-hour ambient gound-level concentrations in the CO_2 well field were estimated by model VALMOD. VALMOD is a Woodward-Clyde Consultants modification of EPA's VALLEY Model. VALLEY was developed to allow treatment of terrain impingement effects in rural settings. It has been specified as the reference model for complex terrain situations by the Workbook for the Comparison of Air Quality Models (Smith et al. 1977). Detailed descriptions of VALLEY Model algorithms are provided in the VALLEY Model User's Guide (Burt EPA 1977). A short discussion follows.

VALLEY is designed to calculate annual and 24-hour concentrations at a grid of 112 receptors from a joint frequency distribution of wind speed, wind direction, and atmospheric stability. Sources - point or area - can be positioned at any location. First-order depletion mechanisms can be treated. The following modifications have been made to VALLEY in its conversion to VALMOD:

1. The receptor grid locations have been placed on concentric circles.

2. The radii of these circles need not be multiples of the innermost circle.

Table A-2. CONSTRUCTION GASEOUS EMISSION FOR A WORST CASE YEAR

Source	Location	Emissions (Ton/Yr) CO	HC	NO_x	SO_2	Particulates
Well Facilities	CO_2 Well Field	49.7	2.2	10.1	0.8	0.6
Central Facilities	CO_2 Well Field	517.8	22.9	97.2	6.6	6.2
Small Pipeline	CO_2 Well Field	123.9	6.3	40.1	2.9	2.2
Origin Station	CO_2 Well Field	4.2	0.2	0.8	0.1	0.1
Total		695.6	31.6	148.2	10.4	9.1
Main Pipeline	Main Pipeline	758.2	38.5	245.6	17.5	13.5
Pipeline Compressor Station	Main Pipeline	85.3	3.5	15.4	1.1	1.0
Maintenance Facilities	Main Pipeline	16.6	0.8	3.2	0.2	0.2
Total		860.1	42.8	264.2	18.8	14.7
Well Facilities	Oil Field	42.2	1.8	8.6	0.7	0.5
Booster Compressor Stations	Oil Field	170.6	7.0	30.7	2.2	2.1
Gas Treatment Plant Plant	Oil Field	550.8	24.3	103.4	7.0	6.6
Flow Lines	Oil Field	9.2	0.5	3.0	0.2	0.2
Total		772.8	33.6	145.7	10.1	9.4

Table A-3. CO_2 WELL FIELD EMISSIONS DURING OPERATION PHASE

Source	Dioxide (SO_2) (tons/yr)	Total Nitrogen Oxide (NO_x) (tons/yr)	Total Suspended Particulates (TSP (tons/yr)	Carbon Monoxide (CO) (tons/yr)	Total Hydrocarbons (tons/yr)
Shell Main Facility	8.7	3.9	0.9	0.60	0.10
Shell McElmo Creek South	2.2	12.0	0.2	0.10	0.023
Shell Moqui Facility	0.9	0.4	0.1	0.03	0.03
Shell Yellowjacket West	1.2	0.5	0.1	0.07	0.03
Shell Doe Canyon East	4.1	1.8	0.2	0.20	0.03
Shell Doe Canyon West	2.2	1.0	0.1	0.03	0.10
Mobil Facility 1	3.1	1.4	0.3	0.21	0.03
Mobil Facility 2	6.2	2.7	0.6	0.38	0.07
Mobil Facility 3	3.1	1.4	0.3	0.21	0.03
Mobil Facility 4	3.1	1.4	0.3	0.21	0.03
Mobil Facility 5	3.1	1.4	0.3	0.21	0.03
Mobil Facility 6	3.1	1.4	0.3	0.21	0.03
Mobil Facility 7	3.1	1.4	0.3	0.21	0.03
Mobil Area 1	1.9	1.0	0.2	0.14	0.03
Mobil Area 2	1.9	1.0	0.2	0.14	0.03
Mobil Area 3	1.9	1.0	0.2	0.14	0.03
Mobil Area 4	1.9	1.0	0.2	0.14	0.03
Mobil Area 5	1.9	1.0	0.2	0.14	0.03
Mobil Area 6	1.9	1.0	0.2	0.14	0.03
Mobil Area 7	1.9	1.0	0.2	0.14	0.03
Total	57.4	26.7	5.4	3.65	0.78

Table A-4. MODEL INPUT PARAMETERS

Parameter	CO_2 Field Main Central Facility	Oil Field 6000 HP Compressor
Stack Height	10 m (30 feet)	12 m (40 feet)
Volumetric Flow Rate	6.0 m^3/sec (12713 cfm)	11.7 m^3/sec (24790 cfm)
Exhaust Temperature	310°K (99°F)	700°K (888°F)
Ambient Temperature	283°K (50°F)	289°K (60°F)
Ambient Pressure	816 mb	890 mb

3. Concentrations may be computed at up to 480 receptors, instead of at only 112.

4. Output is provided in tabular form; output for graphics plotting of concentration contours is also available.

None of the above modifications altered a concentration computation algorithm of VALLEY; only the input and output formats were modified and, in particular, the receptor location grid was altered. Concentrations computed by VALMOD at a given location will be identical to concentrations computed by VALLEY. A validation of VALLEY documented by Burt and Slater (1977), found that VALLEY provided maximum 24-hour calculated concentration within a factor of two of the observed second-highest observed concentrations. It has been specified as the reference model for complex terrain situations by the Workbook for the Comparison of Air Quality Models (Smith et. al., 1977)

In applying VALMOD to the CO_2 well field, it was assumed that the terrain is flat. This was done because all but one of the central facilities, including the Main Central Facility, would be located on high mesas. Thus plume impaction on higher terrain would not occur.

To compute annual concentrations, the annual joint frequency distribution of wind direction, wind speed, and atmospheric stability was retained from a year of wind monitoring data recorded by Meteorological Monitoring Station No. 3 (Figure 2-1). This station was located on a high mesa and should be representative of wind characteristics at most of the central facilities. Emissions were assumed to be continuous; Table A-3 contains the emission rates. A stack height of 10 meters and an effluent temperature of 310°K were input as stack parameters, along with the calculated volumetric flow rate for each facility. Input parameters are given in Table A-4 for the Main Central Facility. An annual afternoon mixing depth of 2600 meters was assumed (Holzworth 1972). This is the depth of the atmosphere in which pollutants are free to disperse. Predicted concentrations were calculated at distances from .07 to 7 km in sixteen directions and reduced to the equivalent concentration at standard temperature and pressure.

To predict 24-hour maximum concentrations, the 24-hour option of the VALLEY model was utilized. The chosen meteorological conditions were those which would produce the largest ground concentrations, as determined by the EPA's PTMAX model. (A slightly unstable atmosphere with a 3.0 meter per second wind speed). The assumed mixing depth was 1200 meters, equal to the average afternoon mixing height (Holzworth, 1972). Otherwise, the input to VALMOD was identical to that of the annual case.

Three-hour average concentrations were also estimated for the Main and Moqui central facilities. The Shell Main Facility was examined

because it would be the largest source and would produce the largest ground level concentrations. The Shell Moqui Facility was examined because it is the source located closest to the Main Facility. Concentrations were estimated by first identifying worst case meteorological conditions using the EPA's PTDIS model which yields 3-minute average concentrations. These values were then converted to 3-hour average concentrations by the use of power laws (Gifford 1975).

Because the McElmo Creek Central Facility is surrounded by higher terrain, it might be possible for the pollutant plume to impinge upon the valley walls. Ground-level concentrations would be highest when the plume had less time to disperse before meeting the rising terrain. Accordingly, worst case meteorological conditions chosen for the impingement calculation were a moderately stable atmosphere (Pasquill Class F) with a wind speed of 1 m/sec (at a reference level of 10 meters). The assumed stack parameters were identical to those of the Main facility. The SO_2 emission rate was 0.063 g/sec. Dispersion coefficients made allowances for the effects of buoyant plume growth and averaging time (Hanna et al. 1977). The plume would rise 67 meters above the facility elevation, where the wind would be 1.77 m/sec. If it is assumed to parallel sea level, this plume would reach the ground at an elevation of 5700 feet. The 3-hour SO_2 concentration was calculated at the closest elevation of that height (0.38 km to the south-southwest).

APPENDIX A-4

OIL WELL FIELD MODELING OF POLLUTANT CONCENTRATIONS

Annual ground-level concentrations resulting from compressor emissions (Table 3-3) were estimated by model VALMOD, described in Appendix A-3. However, because the compressors will be located in a flat rural area, the artificial enhancement of the vertical dispersion - originally developed from an urban area (Tikvardt 1978) - was deleted. Instead, the plume rise was reduced by 30 percent to account for the strong wind shear and increased turbulence close to the ground (EPA 1977).

The terrain was assumed to be flat. The annual joint frequency distribution of wind direction, wind speed, and atmospheric stability was obtained from the National Climatic Center's STAR program results for Hobbs, NM (30 miles to the south-southwest). Emissions, calculated as described in Appendix A-2, were assumed to be continous; Table 3-1 contains the emission rates. The stack height was assumed to be 40

feet, high enough to avoid wake downwash effects. Table A-4 contains other stack parameters used. The compressors, assumed to be twenty in number, were represented as a square area source with a side of 68 meters. The annual afternoon mixing height was 2200 meters (Holzworth 1972). Predicted annual concentrations were calculated at receptors from 0.05 to 7 km in 16 directions and converted to equivalent concentrations at standard temperature and pressure conditions.

Short-term (1- and 3-hour) concentrations were estimated from the EPA's PTMAX model (Turner and Busse 1973). The maximum 3-minute concentrations were found to occur under slightly unstable atmospheric conditions (Pasquill Class C) with a 15 m/sec wind. Concentrations were converted to equivalent concentrations at standard temperature/pressure conditions and corrected to averaging times of 1 and 3 hours by the application of a power law factor (American Meteorological Society 1978).

APPENDIX B

SOILS

The water-induced soil erosion rate was estimated by the use of the Universal Soil Loss Equation developed by the U.S. Soil Conservation Service (1977) to determine erosion losses on agricultural lands. Application of this methodology is intended to provide relative magnitudes of soil losses over large areas; it is not intended to indicate exact soil losses for any specific site.

The Universal Soil Loss Equation is defined as A = RKLSCP, where

A = computed soil loss in tons per acre per year
R = measure of the erosive force in a normal year's rain
K = soil erodibility factor
LS = topographic factor, accounting for the slope length and gradient
C = vegetative ground cover factor
P = erosion control practice factor

In applying this equation to such a large area, the following assumptions were made:

1. Slope length equals 100 feet for all soil loss calculations.

2. The overall slope of disturbed lands in the CO_2 well fields is 2 percent.

3. The dominant soil association in the Wasson Oil Field is the Amarillo-Arvalla soil association; the overall slope throughout this area is 1 percent.

4. The width of surface disturbance along the main CO_2 pipeline right-of-way is 50 feet.

5. No landslides or similar mass earth movements would be initiated during the life of the project.

6. Prior to disturbance, the soil surface has a 35 percent (average) vegetative ground cover with a short brush canopy.

7. Neither construction nor operation and maintenance activities would alter the K values of the disturbed soils from their predisturbed values.

8. Although the proposed construction period for the project is 2 years, it is assumed that for any given parcel of soil the length of surface disturbance during construction would be 1 year.

9. The soil surface, once disturbed from construction and/or operations and maintenance activities is completely bare. Once the disturbance has ended, it revegetates through natural processes to its predisturbed state over a 12-year period according to the revegetation schedule shown in Table B-1.

10. The overall effectiveness in reducing soil losses of the erosion control program is assumed to be 20 percent during the construction year and 30 percent on the lands disturbed during the 30-year operation and maintenance period.

11. Operation and maintenance activities would accelerate the soil loss rate above the natural rate on some portions of the CO_2 and oil fields, but the effect on the pipeline right-of-way would be negligible.

Soil losses would be reduced by two factors: (1) natural revegetation and (2) man-implemented measures such as reseeding and construction of water ditches and channels. These two factors are represented in this application of the USLE by the C and P variables, respectively. By combining them, the expected overall effectiveness of the erosion control program can be accounted for in the equation. If the expected effectiveness were expressed in terms of percent reduction of soil loss from a bare soil state with no erosion control, then

$$CP = 1 - \frac{\%\ \text{Reduction}}{100}$$

The expected percent reduction of a well-managed program has been estimated to be between 50-90 percent (Thronson, 1973).

As is apparent in Table B-1, the C variable varies inversely with the extent of ground cover. Utilizing this relationship as a given, and establishing common-sense guidelines to the estimates of the erosion control program's effectiveness, the value of P for any given year can be estimated. For example, during the construction year, in which the expected effectiveness is 20 percent and revegetation has not yet begun, C = 1.0, CP = 0.8, and, therefore, P = 0.8.

Table B-1. ASSUMED SCHEDULE FOR VEGETATION TO RETURN TO BASE LEVEL GROUND COVER CONDITION

Year	Ground Cover from Natural Revegetation (%)	"C" Value
Construction Year	0	1.0
1	1	.93
2	4	.74
3	10	.45
4	15	.27
5	20	.20
5	24	.15
7	27	.14
8	29	.13
9	30	.13
10	31	.12
11	32	.12
12	33	.12

The following table presents the C and P values used in this application of the USLE.

Table B-2. ANNUAL SCHEDULE OF C AND P VALUES THROUGHOUT PROJECT LIFE

Year	% Natural Groundcover	C	P	Expected Effectiveness Of Erosion Control Program	CP
Construction	0	1.0	0.8	20%	0.8
1	1	.93	0.75	30%	.7
2	4	.74	0.68	50%	.5
3	10	.45	1.0	55%	.45
4	15	.27	1.0	73%	.27
5	20	.20	1.0	80%	.20
6	24	.15	1.0	85%	.15
7	27	.14	1.0	86%	.14
8	29	.13	1.0	87%	.13
9	30	.13	1.0	87%	.13
10	31	.12	1.0	88%	.12
11	32	.12	1.0	88%	.12
12	33	.12	1.0	88%	.12
Operation and Maintenance Period (30 yr)	0	1.0	0.7	30%	.70

To illustrate the overall calculation procedure, an example has been prepared. In Sandoval County near MP 175 of the proposed route, the alignment would cross 4.3 miles of the Las Lucas-Little soil series, for which the K value has been tested to equal 0.49. In this area the R and LS values equal 40 and 0.10, respectively. Thus, for this particular area,

$$A = (40 \times .49 \times .10)(CP)$$
$$A = (1.96)(CP)$$

Using the CP valves contained in Table B-2, the rate of potential soil loss during the period in which the soil loss rate is greater than the natural erosion rate is summed in Table B-3.

TABLE B-3: POTENTIAL ANNUAL SOIL LOSS INCURRED FOR A REPRESENTATIVE 4.3 MILE LONG SECTION OF PROPOSED PIPELINE DURING CONSTRUCTION AND REVEGETATION PERIODS.

Year	Potential Soil Loss (tons/acre)
Construction Year	1.57
1st Year of Revegetation Period	1.37
2nd " " " "	0.98
3rd " " " "	0.88
4th " " " "	0.53
5th " " " "	0.39
6th " " " "	0.29
7th " " " "	0.27
8th " " " "	0.25
9th " " " "	0.25
10th " " " "	0.24
11th " " " "	0.24
12th " " " "	0.24
Total during 13 year period	7.5

Note that through the use of Assumption eleven, the 30-year operation and maintenance period is excluded from this summary.

The next step is to convert the length of this 4.3 mile segment into an area (acres) through the use of Assumption 4. This area is calculated to be 26.1 acres, which is multiplied by 7.5 tons/acre/year to drive the total potential soil loss. The result is 195 tons.

The potential soil loss impact of the project on this 4.3 mile section would be the difference between 195 tons and the amount that would have occurred through natural processes over the same period. The period is 13 years (1 construction and 12 revegetation years). The natural, annual erosion rate can be calculated by extending the CP schedule shown on Table B-2 to include the year following the revegetation period in which the vegetative ground cover has returned to its predisturbed condition, i.e., 35 percent. The CP value for this condition is 0.11, therefore the natural, annual erosion rate = 1.96 x 0.11 = 0.22 tons/acre. Thus the potential soil loss impact is 195 - (.22)(26.1)(13) = 120 tons.

APPENDIX C

VISUAL RESOURCES

GENERAL METHODOLOGY

Visual resources in the vicinity of the proposed project were inventoried and evaluated in accordance with appropriate BLM and USFS guidelines and manuals. The Visual Resource Management (VRM) System is implemented by accomplishing the following steps:

- regional baseline visual resource inventory and evaluation
- visual resource contrast rating for site-specific projects
- visual resource project planning and design

The objective of VRM is to systematically identify scenic quality and to set management standards for the use and protection of visual resources by classifying public lands into one of five VRM classes. A general description of the VRM system follows.

Visual Resource Inventory and Evaluation

Identification of landscape scenery units is the first inventory step. Landscape scenery units are grouped according to similarities in the following attributes:

- landform
- vegetation
- water
- color
- influence of adjacent scenery
- scarcity
- cultural modifications

The landscape is scored according to characteristics in each of the above attributes; the sum of the seven scores identifies the landscape as being either outstanding, characteristic, or common. This score should be an indicator of the assessed landscape's most remembered visual character.

Assigning a visual sensitivity level to an area is the second inventory step. Sensitivity level boundaries are determined by mapping pedestrian and vehicular use volume, key observation points, seldom seen areas and potential areas of critical concern for scenic values (by government policy). This information is combined with a user attitude survey to arrive at a final visual sensitivity level. The high, medium, or low level rating would represent the public sensitivity or projected reaction to change in the landscape character.

The third step is identifying visual distance zones in high and medium sensitivity level areas. Foreground-middleground and background zones are identified as the area seen from key observation points.

Foreground-Middleground. This is the area that can be seen from each travel route or sensitivity area for a distance of 3 to 5 miles where management activities might be viewed in detail.

Background. This is the remaining area which can be seen from each travel route, to approximately 15 miles.

The fourth step in visual resource inventory and evaluation is the analysis of scenic quality, sensitivity level, and distance zone maps in order to determine an area's visual resource management class. These five classes outline the degree of modification allowed in the form, line, color and texture of land and water bodies, vegetation, and structures. The five classes are:

- Class I: This class provides primarily for natural ecological changes; management activities are to be restricted and are not to attract attention.

- Class II: Changes in basic elements by management activities should not be evident in the characteristic landscape.

  Class III: Contrasts to the basic elements may be evident and begin to attract attention, but they should remain subordinate to the existing characteristic landscape.

- Class IV: Alterations may attract attention but should repeat the line, form, color, and texture elements of the characteristic landscape.

- Class V: Rehabilitation is needed to restore the landscape to the character of the surrounding landscape.

Visual Resource Contrast Rating

The objective of the visual resource contrast rating system is to provide a measure of whether a proposed action will meet the requirements of the assigned VRM classes. The degree to which a management activity adversely impacts the visual quality of a landscape depends on the extent of visual contrast that is created between the activity and the existing landscape character. Contrast is measured by separating the landscape into land and water surfaces, vegetation, and structures, and then predicting the magnitude of change in contrast with the basic elements (form, line, color and texture) for each of the three major features. Assessment of the degree of contrast will indicate the severity of impact and would guide the plans for mitigating the contrasts to meet the requirements of the VRM classes. Contrasts are considered from the most critical viewpoints for distance, angle of observation, length of time, relative size of the project, season of the year, light, and the effects of time on the healing process.

The following parameters are applied to determine if the proposed activity will meet the requirements of the assigned VRM classes.

- Class I: The degree of contrast for any one element may not exceed a weak degree of contrast (1x) and the total contrast rating for any one feature may not exceed 10.

- Area of Critical Environmental Concern: The degree of contrast for any one element should not exceed a moderate value (2x), and the total contrast rating for any feature may not exceed 10.

- Class II: The degree of contrast for any one element may not exceed a moderate value (2x), and the total contrast rating for any feature may not exceed 12.

- Class III: The degree of contrast for any one element should not exceed a moderate value (2x), and the total contrast rating for any feature may not exceed 16.

- Class IV: The total contrast rating for any feature should not exceed 20.

Table C-1 summarizes VRM contrast ratings for the specific project impacts.

Visual Resource Project Planning and Design

The identification of specific contrasts in form, line, color, and texture indicate the problems that could allow design mitigation. By applying design procedures to proposed actions, visual contrasts can be eliminated or reduced to potentially meet the visual planning objectives that are stipulated in the VRM class designations. Once a project has been designed to reduce visual contrasts, it is reassessed by the visual contrast system to determine if the project can meet the area's visual goals and, if not, to what degree the landscape's visual resource would be impacted.

SHORTHAND METHODOLOGY

For the most part, the impact and mitigation analysis of this report was based on VRM inventory and classification already completed by the BLM in Colorado and New Mexico. However, the pipeline corridor between the Rio Grande and Pecos River area had not yet been classified according to VRM criteria. In this corridor, a shorthand evaluation methodology recommended by the BLM New Mexico State Office was used to approximate the appropriate VRM classes. The conclusions reached by the analysis are tentative, pending further inventory by the BLM. The shorthand inventory was accomplished in two stages, the first being a review

Table C-1. VISUAL CONTRAST RATINGS

Project Impact	Features: Land/Water	Vegetation	Structures
Pipeline Intersection with I-25 at Augostora (VRM Class II)	3	13	3
Compressor Station (VRM Class IV)	10	17	23
Transmission line to compressor station (VRM Classes III & IV)	3	10	26
Pipeline: Placitas and intersection with Scenic Highway 14 (VRM Class II)	8	23	0
Pipeline: Intersection with U.S. 54 at Duran (VRM Class III)	8	19	7
Ramon microwave tower (VRM Class IV)	3	10	27
Duran Mesa microwave tower (VRM Class III)	10	17	23

of available maps and information, the second being a field check of information developed in the above review.

The methodology conformed to the following format and logic:

Scenic Quality

Areas of relatively high scenic quality, corresponding to BLM classes A and B, were defined as areas having some of the following characteristics:

- considerable landform relief
- colorful rock outcroppings
- variety of vegetation
- relatively few man-made intrusions
- perennial water features

Areas of relatively low scenic quality (analogous to BLM Class C) were those areas which were largely flat and featureless, with uniform and monotonous vegetation.

Visual Sensitivity

Areas of moderate to high visual sensitivity were generally defined as follows:

- areas visible from scenic highways or tourist routes
- wilderness or primitive areas
- parks and recreation areas
- resort, retirement, and second home areas
- recreational water bodies
- areas experiencing considerable back country, recreational vehicle, or undesignated camping use

Areas of low sensitivity were those which were seldom seen. In the event of a question concerning the degree of sensitivity, the following criteria shown in Table C-2 were used.

Some allowance was made for probable public response to physical alteration of the landscape in areas that appeared to receive some local attention or which had been included in general planning documents (e.g., proposed recreation trails in New Mexico, local scenic routes).

VRM Classes

VRM classes for each of the study regions were determined by applying the matrix presented in Table C-3 to the scenic quality and visual sensitivity determinations.

Table C-2. SHORTHAND METHODOLOGY CLASSIFICATION MATRIX

Visual Sensitivity	Scenic Quality High	Scenic Quality Low
High	VRM Class II	VRM Class III
Low	VRM Class II	VRM Class IV

Note: Areas of high scenic quality = Class II.

Areas of high visual sensitivity = Class III. (not overlapping high scenic quality)

Remainder of corridor = Class IV.

Resources for the visual analysis included:

- BLM VRM class designations
- USGS topographic quad sheets
- Vegetation maps
- Geologic maps
- Aerial photographs of the well field and pipeline areas
- USFS Landscape Management Classifications for Cibola National Forest and San Juan National Forest

A one-to-one correspondence was assumed between USFS Landscape Management Classifications and the VRM system (Table C-3).

Table C-3. COMPARISON OF BLM AND USFS CLASSES

BLM VRM Classes	USFS Landscape Management Classes
Class I	P - Preservation
Class II	R - Retention
Class III	PR - Partial Retention
Class IV	M - Modification
Class V	REH - Rehabilitation

APPENDIX D

WELL FIELD DEVELOPMENT PLAN

SUMMARY

An ancillary effort to environmental studies was the elaboration of a well field plan based primarily on environmental, geologic, and archaeological constraints. The objectives of this planning study were to identify features and conditions in the CO_2 well field that influence suitability for placement of wells, roads, gathering lines, and compressor stations. The study was done using computer graphic techniques, to facilitate statistical manipulation of data and to produce graphic results that were easily comprehended. A major interim step of the planning study was the development of a model to predict levels of significance of archaeological resources in the well fields. High-value archaeological and environmental areas and hazardous geological areas were recommended for avoidance. The predictive approach is not intended to substitute for required archaeological clearances during construction; standard field procedures for survey, avoidance, and mitigation will be enforced at all construction sites on public land. The intended use of the Well Field Development Plan was the planning of the optimum well field layout; in this sense it provided a mitigative orientation to the description of the proposed action (Chapter 1). Some of the archaeological data used in the planning study, as well as the predictions and interpretations developed from these data, are confidential and proprietary to the Colorado and federal governments.

The objective of this study was to develop a multidisciplinary graphic planning tool that could provide a basis for improving the well field design by minimizing potential impacts. The final product of this task is a set of constraint maps that define differential suitability for the physical placement of well field facilities.

Suitability was assessed in relation to three major planning objectives:

- avoidance of significant archaeological resources
- minimization of environmental impacts
- avoidance of potential geologic hazards

Separate maps were developed showing archaeological, environmental, and geologic constraints to development. Values shown on these maps were weighted and combined into a single "composite constraints map". In planning the well field layouts, these constraint maps were used as guides to facility configuration.

Planning objectives were developed out of conversations between Shell, Mobil, and federal review agencies. The presence of archaeological resources was seen at once as the most pressing issue to be addressed in a well field plan; it was also assessed the most difficult to study since much of the well field area has not been surveyed for sites. Other issues that could influence the specific locations of well field facilities were identified to be the nature and potential severity of environmental impacts and the potential for geologic hazards (primarily in connection with slope stability).

The planning process began with the assembly and preparation of an extensive data base. These natural data were subsequently machine-digitized. For analytical purposes, grid maps were developed. The size of the grid cell is 400 by 400 feet, approximately 3.67 acres. Data were interpreted, analyzed, and displayed with respect to each individual cell.

Four separate suitability models - geologic, environmental, archaeological, and trade-off - were developed.

The geologic model began with source data on the geology, topography, and elevation of the well field area. Topography and elevation were machine-interpreted to yield a slope map, which was then interpreted with respect to relationships among material type, thickness, and slope to yield a slope stability map. Stability classifications combined with proximity to potentially active faults defined relative geologic suitability for development in each cell.

The environmental model considered land uses and biological communities. Land uses were scaled in order of importance based on their local extent, regional importance, and economic significance. Biological communities were scaled in terms of their uniqueness, productivity, and restoration potential. Land use and biology were combined in a trade-off function that yielded a single index of environmental suitability for development in each cell.

The archaeological model was designed to predict the probable levels of significance of archaeological resources at all locations in the well field. Construction of the prediction model required the analysis of large amounts of geographic, geologic, and environmental data in relation to the locations and types of existing surveyed archaeological sites. Ultimately, a strong correlation was identified between several empirical predictor variables and archaeological site significance. This multiple correlation, when applied to measurements of the predictor variables in each cell, yielded a prediction of the level of archaeological significance.

Concurrently, the subjective attitudes of professional archaeologists toward differing levels of site significance were formally assessed and expressed as a preference function; this function measures the perceived difference between points on a scale of site significance, as well

as the archaeologists' attitudes toward risk.* The predicted value of archaeological resources in each cell was interpreted in terms of the preference function, and an "equivalent significance value" was computed. This value incorporates both the computer prediction and the professional archaeologists' subjective assessments of its meaning. Suitability for development in each cell is defined as the inverse of the equivalent value. Even though specific archaeological clearances will be required for all construction on public land, this predictive approach was pursued in order to contribute to the understanding of the regional archaeological resource, and thereby increase the appropriateness and quality of the well field plan.

Finally, a trade-off model combined the suitability values for each cell from the geologic, environmental, and archaeological models to yield a composite measure of suitability. Trade-offs were determined in a formal interview of the multidisciplinary project team; another group of interviewees with different frames of reference could express a different set of trade-offs. The trade-offs used in this model are thought to be reasonable and appropriate in relation to the characteristics of the project area and the expressed concerns of the federal review agencies.

The suitability values of each model were calculated on a cell-by-cell basis, and cells were machine-plotted at a scale of 1:24,000. These cell plots were superimposed on base maps of the well fields and colored to portray differential suitability. Well field layout can be manually superimposed on these constraint maps, and modified on a cell-by-cell basis to avoid or minimize incursion into higher value areas. Alternate routes for access roads and gathering lines can be evaluated also, on the basis of the distributed and aggregate values of the cells traversed.

CONFIDENTIALITY OF DATA AND RESULTS

The locations and descriptions of archaeological sites in the well field area were developed under previous contract work for the federal government. This information is confidential and proprietary to the federal government, and is not subject to disclosure under the Freedom of Information Act. Similarly, interpretations and predicted site locations based on these data are to be considered confidential and not available for disclosure. For this reason, none of the maps produced in this study are attached.

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*Professional archaeologists participating were Dr. David A. Breternitz, Director of the Mesa Verde Regional Research Center and a Professor of Archaeology at the University of Colorado; Al Kane, Ph.D. candidate, Department of Anthropology, University of Colorado; Dr. Douglas D. Scott, BLM District Archaeologist, Montrose, Colorado; and Gary Matlock, Colorado State BLM Archaeologist (now BLM Area Archaeologist, Durango, Colorado).

The previous uses of the CO_2 well field are of great interest; plateaus and canyons were the locus of an important prehistoric culture, the Anasazi. These peoples, the possible antecedents of the modern Pueblo Indian groups of the Southwest, occupied the area for 800 years, between about A.D. 450 and 1300. In addition, there is some evidence in this area of seasonal or sporadic presence of peoples from the Paleo-indian and Archaic periods (10,000 B.C. to A.D. 450). The Anasazi built numerous pit houses, large habitations of stone and adobe, and ceremonial structures, as well as smaller specialized edifices such as towers and shrines. At the height of their occupation, several times as many people lived in the area as presently live there.

Only a fraction of the leased lands has been formally surveyed for cultural sites; the density of recorded sites within and close to the CO_2 leases is highly variable, ranging from zero to more than 100 sites per square mile.

Site distribution within the unsurveyed portions of the lease areas may be expected to be as variable as in the areas that have been closely studied. Consequently, planning of any construction activities proposed for the unsurveyed lease areas is subject to uncertainties associated with the unknown locations of cultural sites. Unexpected encounters with significant cultural sites can delay the progress of construction while appropriate survey or mitigation procedures are implemented. In addition to the prospect of inadvertent cultural discoveries during construction, professional archaeologists have expressed great concern regarding the possible acceleration of intentional and unauthorized removal of cultural artifacts.

The main obstacle to advance resolution of both applicant and government concerns over the risk of developing this archaeologically rich area is the uncertainty of cultural site locations and types. The traditional approach to reducing this uncertainty would be a comprehensive physical survey of the entire lease. Because of the size of the project area and its suspected archaeological content, this would be prohibitively time-consuming and costly, and could contravene the government's interest in minimizing exposure, and hence vandalism, of cultural properties.

As an alternative to a pre-planning physical survey, a statistical approach to uncertainty was selected; this was feasible because recognized expert scientific judgment and a well-documented data base (of several hundred sites within and adjacent to the lease areas) were available. Such an approach was desirable because it offered time- and cost-effectiveness, greater flexibility, and minimum risk of public exposure of findings. Specific facility sites and alignments on public land will always be surveyed in conjunction with required archaeological clearances.

The multidisciplinary data base needed to model the archaeological uncertainty problem was to be useful for other purposes also. Geologic

and environmental suitability models were developed from these data and incorporated along with the archaeological model into a broad environmental planning framework. The decision to use a formal analytical approach to the archaeological question is compatible with the development of a set of other planning tools through which alternative well field concepts could be evaluated in relation to individual or multiple resources.

APPROACH

The Graphic Technique

All the data used in this task were compiled, analyzed, and presented by a computer graphic system. Source data were initially taken from existing published maps, or source maps were manually prepared on the basis of published literature and field observations. These source maps were machine-digitized, so that data were stored in natural form on magnetic tape.

Subsequent analysis and presentation of the data were done with respect to a cell grid, in which the ground dimensions of a cell were 400 by 400 feet. Interim interpretive or analytical steps were based on and resulted in computer map files that reference all inputs and outputs to specific locations in the cell grid. The grid is referenced to State Plane Coordinates on topographic maps of the study areas. Output from the system (any of the map files) is available in tabular, numeric, or graphic form; the final graphic products of the planning task were displayed as plan dimension cell plots superimposed on a printed 1:24,000 scale topographic base map.

Methodology

The approach consisted of six steps:

1. Definition of Objectives. This step identified prevailing issues that influence developmental suitability in the well fields and set forth planning objectives in relation to these issues. Suitability was defined in relation to the degree of achievement of these objectives, as reflected in the well field design.

2. Selection of Criteria. This step began by refining the planning objectives and expressing them in relation to measurable features of the well fields. Rules were then established for evaluating such features in terms of suitability for well field development. For example, the general planning objective "minimizing environmental impacts" was refined to include (in part) minimizing the disturbance to specific biological communities that could be mapped; those communities were then ranked in order of their ecological importance, and a technique

for expressing their relative suitability for development (a utility function) was set forth. Hence, this step established the basis on which suitability for development in each cell of the well field grid would be determined.

3. Development of a Data Base. In this step, all the data that would be needed to measure the selected criteria were assembled in map format and digitized. Some of the planning criteria were measurable only in terms of highly interpreted data (e.g., relative significance of predicted archaeologicla sites); the background data needed to produce such interpretations were also compiled in digitized form in this step. The product of this step was a set of source data maps, compiled electronically on magnetic tape.

4. Preparation of Interpretive Maps. In this step source data maps were interpreted to yield the more refined data needed for subsequent analyses. These interpretations ranged from the simple (such as elevation in a cell, interpreted from topographic source maps) to the very complex (such as the prediction of archaeological site significance, interpreted in several steps from numerous source maps and regression analysis). In some cases, the preparation of interpretive maps required the construction and testing of analytical models. Most of the interpretive maps were retained as computer files, and were not plotted.

5. Preparation of Constraint Maps. This step involved electronically combining sets of source and interpretive maps in accordance with the criteria that were selected to define suitability. For example, maps describing the relative importance of land uses and the relative importance of biological communities were combined in accordance with a tradeoff function to yield an "environmental constraints map"; this map shows increasing degrees of constraint to development (i.e., differential suitability) as defined by the combined interpreted values of land use and biology in the well fields. Four sets of constraint maps were prepared: archaeological, geologic, and environmental constraints, and a weighted composite of these three.

6. Well Field Layout Planning. In this step, the maps prepared above are used in selecting the locations of well field facilities. This is an iterative process, where alternate locations can be evaluated in terms of the constraints imposed by individual or multiple resources. The intent is to optimize the well field designs so that achievement of the planning objectives is improved. This was done manually, using transparent overlays of the tentative designs superimposed on constraint maps. The locations and routes of well field facilities were

modified directly on the transparency to avoid high-constraint (low-suitability) areas; this process continued until a final design was developed that represents a high level of achievement of the planning objectives consistent with the limitations of reservoir geology, sound engineering practice, and economics.

IMPLEMENTATION AND FINDINGS

This section details the work conducted in each step of the approach, and the findings of each step.

Definition Of Objectives

From 1976 to 1978, a series of discussions was held between the applicants and representatives of federal and state agencies who would participate in the environmental review of the proposed CO_2 project. One purpose of these meetings was to identify environmental or developmental issues that should be addressed in planning the layout of well field facilities and that could help to differentiate between specific locations within the well field, on the basis of suitability. The issues receiving the most attention were the protection of cultural properties (archaeological sites) and the minimization of environmental impacts (in terms of rare and endangered species, important biological communities, and land use). Preliminary inventories of the well field area added another issue: avoidance of geologic hazards, mainly in relation to slope stability.

Planning objectives developed in relation to these issues were:

- Archaeological
  - avoid encroachment on significant archaeological resources
  - minimize the potential for increased vandalism of archaeological sites by limiting the extension of access to areas where sites are or may be present
- Environmental
  - avoid sensitive or unique biological areas
  - minimize disturbance or removal of important vegetative communities
  - avoid lands of restricted status
  - minimize disturbance of economically important land uses

- Geologic
  - avoid areas close to active or potentially active faults
  - avoid areas with poor slope stability characteristics

Selection Of Criteria

Criteria are the means of measuring achievement of the objectives; the degree to which criteria are satisfied is indicative of the extent to which objectives are achieved. In some cases, there is no choice in the degree to which criteria can be satisfied; for federally restricted and withdrawn lands and known archaeological sites, the criteria are exclusionary. Hence, achievement of the planning objectives referring to avoidance of restricted lands and avoidance of encroachment on known archaeological resources is completely accomplished by the application of exclusionary criteria. For all other objectives, however, the sense of differential achievement is more subtle and amenable to subjective interpretation. For these objectives, the criteria are measures of the relative degree of constraint to development imposed by features, conditions, or resources in the well fields. For each type of resource-archaeological, geologic, environmental-one or more scales were developed to array similar resources in order of the severity of constraint they presented. Thus, for example, a scale of known archaeological sites was constructed in which site descriptions consisting of age, type, size, and multiple occupation history were arrayed in order of importance. This scale initially had more than 180 points, but was reduced to seven categories in which sites were of approximately equal significance. Scales showing the order of importance or relative constraint were also constructed for land uses, biological communities, and the stability of geologic materials.

For each scale, it was necessary to define the differences, in terms of constraint, between each of the points on the scale. On the scale of archaeological significance, for example, the difference between a 1 and a 2 was much less significant than the difference between a 4 and a 5; the appreciation of these differences was subjective, and based on the judgments (preferences) of expert professional archaeologists. It was possible to measure such preferential differences by constructing a "utility function" over each scale. Graphically, the utility function is a picture of the preferences over a scale of values; mathematically, it captures not only the value of any point on the scale, but also its significance relative to all other points on the scale.

By using these scales and utility functions, criteria for the archaeological, geologic, and environmental objectives were expressed in terms of "utility"; a low utility value meant low suitability for development, or (conversely) a high level of constraint. A mathematical equation was derived for each utility function.

Table D-1 summarizes the criteria selected for each of the planning objectives.

<u>Development Of The Data Base</u>

Nine source data maps were prepared and digitized. Most of the work was done at a scale of 1:24,000 on USGS topographic quadrangle maps. The source maps were:

- <u>Land use and soil associations</u>: taken from U.S. Soil and Conservation maps, local planning studies, and field checks.

- <u>Probable prehistoric dry farming areas</u>: prepared by the archaeological consultant, on USGS 7-1/2 minute quadrangle maps.

- <u>Topography</u>: USGS 7-1/2 minute topographic quadrangle maps were digitized.

- <u>Roads</u>: photo-interpreted from 1:24,000 photographic quadrangle maps prepared by the State of Colorado (partial coverage only).

- <u>Geology</u>: taken from USGS geologic quadrangle maps.

- <u>Archaeological sites</u>: prepared by archaeological consultant, on USGS quadrangle maps.

- <u>Hydrology</u>: prepared by the archaeological consultant using the drainage rank system of the Southwestern Anthropological Research Group (SARG); shown on USGS quadrangle maps.

- <u>Biological communities</u>: taken from aerial photographs, literature, and field observations.

- <u>Linear features</u>: shows faults, lineaments, and the contact between the Dakota Sandstone and Morrison Formation (geologic materials).

Except for the linear features map, all maps were digitized as polygons; each polygon had a label. For the archaeological site map, the label was a code of site characteristics with four entries (period, size, type, and condition) for each period of occupation. Each of the source maps was plotted and veritifed against the original data map. the source maps were electronically registered to State Plane Coordinates, so that each source map existed as an electronic file, the geographic locations of which were fixed to a known map system. At the same time, a grid was chosen and registered to the coordinates.

Table D-1. CRITERIA FOR PLANNING OBJECTIVES

	Criteria	
Objective	Basis	Measure
ARCHAEOLOGICAL		
• Avoid known sites	Exclusionary	Known sites excluded
• Avoid areas of significant potential resources	Scale of significance, predictive model	Utility function: shows utility of predicted values
ENVIRONMENTAL		
• Avoid restricted lands	Exclusionary	Withdrawn lands and restricted lands excluded
• Avoid unique biologic communities		Not applied: no such communities present
• Minimize environmental impacts		
- Land use	Scale of significance	Utility function
- Biologic	Scale of significance	Utility function
GEOLOGIC		
• Avoid hazardous areas	Scale of potential hazards: - proximity to faults - scale of stability of geologic materials	Utility function

Preparation Of Interpretive and Constraint Maps

Preparation of interpretive and constraint maps consisted of analyzing or combining the source data maps to obtain measurements of the criteria in each cell of the grid, and then displaying these criteria as differential constraints on maps of the well field area. The process is schematically illustrated in Figure D-1. Conceptually, this step required that four models be developed to guide the use and analysis of data to yield expressions of the criteria for each cell. These models were archaeological predictions and constraints, environmental constraints, geologic constraints, and a trade-off model that combines these three to yield a composite index of constraint for each cell. Each model is discussed below.

Environmental Model. Achievement of the objective of minimizing environmental impacts was measurable in terms of the exclusionary criteria (land status) and in terms of the differential constraints imposed by the particular land uses and biologic communities present in each cell. The importance of a particular land use or biologic community was viewed in relation to the nature and duration of well field construction and operation activities. A general assumption was that construction would involve removal of vegetation and temporary suspension of the current land use; in most cases, the construction area would be revegetated and restored to its former use. The nine different land uses and ten different biological types shown on the source maps were ranked in order of their suitability for the types of construction proposed for the CO_2 project. The five-point scale for land use and the four-point scale scale for biology are shown in Tables D-2 and D-3. Utility functions were assessed over these two scales. The trade-off between biologic and land use impacts was formally assessed, so that in any given cell the combination of land use and biology could be interpreted to yield a single value of environmental constraint. The trade-off effectively gives 61 percent of the environment weight of a cell to biology and 39 percent to land use. The two utility functions were combined into a single function (incorporating the trade-off) that expresses a single environmental constraint value for each cell.

In terms of the computer system, two source data maps (land use and biology) were interpreted in relation to the utility functions, and then combined to yield a constraints map. The result was the environmental constraints map.

Geologic Model. The geologic objectives were to avoid hazardous areas associated with faults and landslides. The source map "linear features" showed active and potentially active faults; this map was interpreted to show portions of the well field within 800 feet of these features. At this distance, effects from a magnitude 6.0 earthquake occuring at the surface on the fault were considered to include fault rupture and

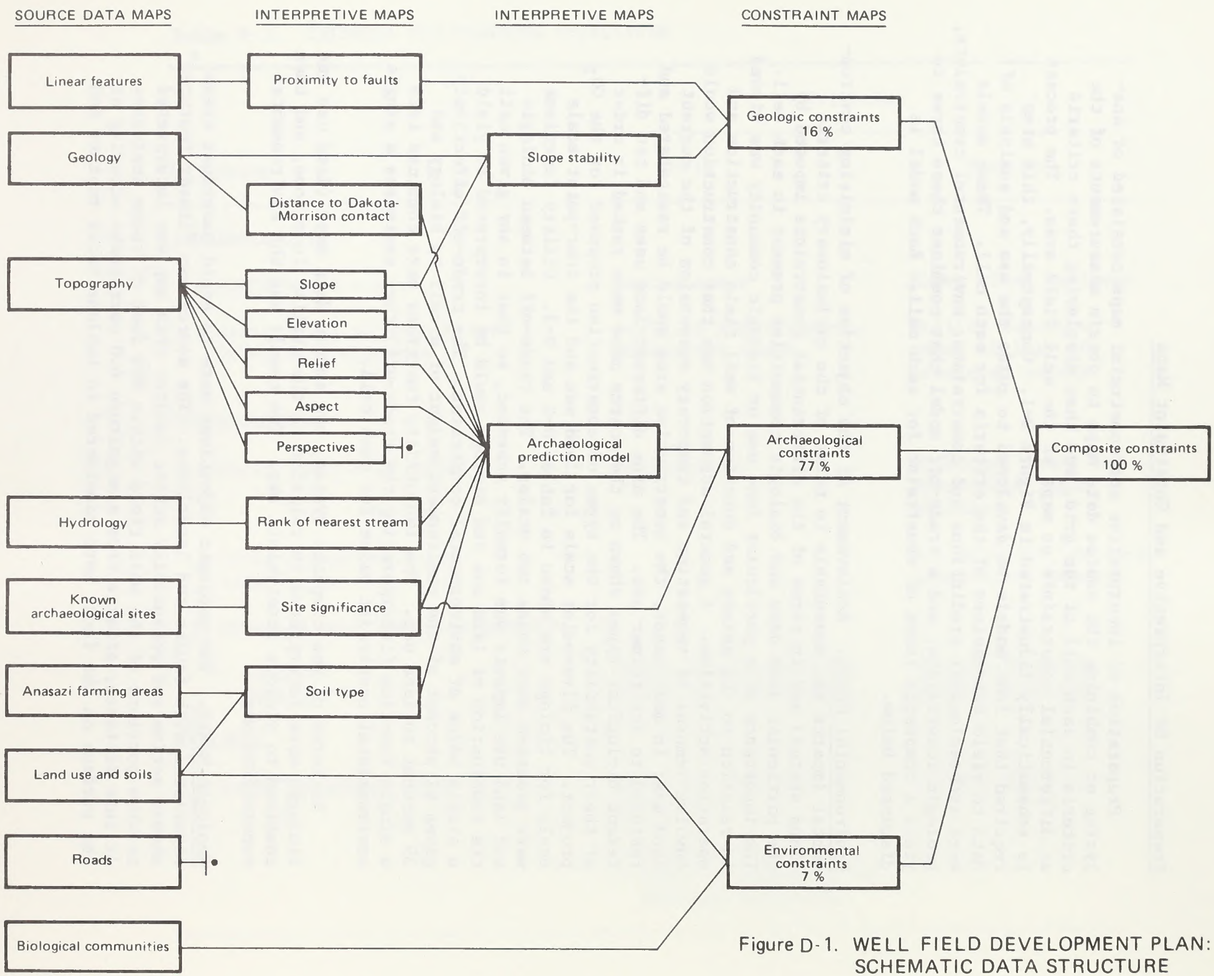

Figure D-1. WELL FIELD DEVELOPMENT PLAN: SCHEMATIC DATA STRUCTURE

Table D-2. ENVIRONMENTAL CONSTRAINTS MAP: LAND USE SCALE

SCALE	Rank
Land Use	
Federal withdrawals	Excluded
Mined areas	1
Dry crops or improved range; unimproved range	2
Irrigated crops; irritated range	3
Timber or woodland; current timber harvest; orchards	4

Table D-3. ENVIRONMENTAL CONSTRAINTS MAP: BIOLOGY SCALE

SCALE	Rank
Vegetative Type	
Cultivated agriculture	1
Grasslands	2
Ponderosa pine forest; aspen; pinyon-juniper; shrub; riparian; chained pinyon-juniper	3
Federal withdrawals	Excluded

and accelerations in excess of 0.5g. Severe shaking from such an event would be experienced throughout the entire well field, so the interpretation focused only on those areas where surface rupture was a possibility.

The potential for landsliding or other slope stability problems was estimated on the basis of a relationship between the type, thickness, and slope at the surface of geologic materials. Material thicknesses were found to be more or less uniform within each of the well field areas. Thus, for the types of geologic materials occurring at the surface in the well fields, a relationship was drawn between material type and slope and one of three classes of stability (stable or probably stable, moderately stable, and potentially unstable). A table showing these relationships is presented as Table D-4.

A slope map was created by interpreting elevations from topographic maps. The slope map contained the percent slope in each cell. A source data map of geology identified each of the geologic materials in each cell. These two maps were electronically combined and then interpreted according to the stability relationships. The resultant map showed slope stability in each cell.

The two map files describing slope stability and proximity to faults were then combined to yield the geologic constraints map. For this purpose, cells within 800 feet of active faults were set equivalent to cells in the worst stability class; thus, the constraints map shows three levels of geologic constraint: stable areas, moderately stable areas, and areas that are either unstable or close to faults or both.

Archaeological Model. The planning objectives for archaeology were to avoid known sites and to avoid or minimize encroachment upon areas that are likely to contain significant archaeological resources. For known sites, the grid cells where a site or portion thereof had been plotted were simply excluded. The more interesting problem was to identify areas likely to contain sites, and differentiate among them on the basis of significance. For this purpose, an analytical model was designed to predict the relative significance of those archaeological resources in the well fields that are found in 400 x 400 ft (3.67 acres) quadrats.

Several hundred archaeological sites have been identified and described in a series of previous partial surveys within the CO_2 well field. Several thousand sites have been similarly catalogued in nearby areas, including Mesa Verde National Park. A few previous experiences with limited statistical analysis of some of these sites (involving multivariate analysis of locational data recovered from site surveys) suggested that a similarity of certain locational characteristics existed among sites of similar types and ages. None of these previous

Table D-4. GEOLOGIC CONSTRAINTS MAP CONSTRAINING FEATURES AND UTILITY FUNCTION

POTENTIALLY ACTIVE FAULTS

Proximity	Effects	Constraints
0-800 feet	Fault rupture and severe shaking	Potentially unsuitable
800-16,000 feet	Severe shaking, felt over most of well field	None
16,000-105,000 feet	Moderate shaking, felt over entire well field	None

SLOPE STABILITY

S = probably stable or stable
M = moderately stable
U = potentially unstable

Formation*	Slope 0-20%	Slope 20-40%	Slope > 40%
Qa	S	M	U
Qe	S	S	M
Qat	S	M	U
Qaf	S	M	U
Qap	S	M	U
Qc	U	U	U
Qcl	U	U	U
Qct	M	U	U
Qgd	S	M	U
TKdu	S	M	M
Km	S	M	U
Kdb	S	S	M
Jm	M	M	U
Jmb	M	U	U
Jmb-D	M	M	U
Jms	S	M	U
Jmws	S	M	U

*See Haynes et al. (1972) for formation names abbreviated in this table.

studies had been designed to predict site locations or types, but the consensus of archaeologists familiar with the project area was that a predictive model was a workable concept. The central premise of the modeling effort was that a quantified correlation could be established between a set of measurable locational variables in the well field and a set of archaeological site characteristics that define significance. The method chosen to find this correlation was multiple regression analysis of locational characteristics of the sites known to exist within the CO_2 well field. Separate but similar models were developed for three areas in the well field. The McElmo Dome and Doe Canyon fields (Shell) were separately modeled because they are geographically separated; the third area, proposed by Mobil, was modeled at a later date than the other two.

The Scale. The first step in this analysis was to define the dependent variable of the regression equation: the measure of site significance. This was accomplished by constructing a scale of site significance. "Site significance" was defined as the potential of a site to contribute to the body of scientific knowledge concerning the cultural mechanisms and adaptations of the Anasazi people and their Archaic predecessors. Four major site characteristics were used to define significance:

- Age. Nine distinct periods of occupation are recognized in the project area. Generally, less is known about the earlier periods than concerning the recent. These nine periods were grouped into five categories of roughly equivalent significance.

- Type. Recorded sites in the area range from small lithic scatters to limited-activity or special-use features to large apartment-like habitations with multiple kivas (pit structures). Generally, habitation sites have the potential for providing a more diversified and larger data base than do other types of sites. Site type was influential in describing the nature and quality-of-information content of a site. Fifteen general types of sites were recognized. These type descriptions were grouped into six different categories of roughly equivalent significance.

- Size. Larger sites can generally provide more information than smaller sites. A distinction was drawn between small sites and those larger than 5000 square meters.

- History of Multiple Occupations. Anasazi sites were occupied for widely varying time spans. Sites with a history of multiple occupations were considered to be more important than single-period sites. Three categories of occupation history were used in the model.

A scale was constructed utilizing different combinations of these site characteristics. The five age descriptors, six type descriptors, two size descriptors, and three multiple-occupation descriptors yielded 180 possible combinations. These were arrayed in order of significance and then grouped into ten categories of approximately equivalent significance. The ten-point scale was later reduced to seven points when a review of known sites in the well field area turned up little or no representation for three points on the scale. This seven-point scale was developed by a team consisting of four professional archaeologists. The scale is believed to conform to prevailing opinions of the professional archaeological community knowledgeable of Anasazi remains. A detailed exposition of the scale is presented in Table D-5.

A utility function was then assessed over the scale of significance. The scale was merely an ordinal listing of site descriptions by significance; the utility function measures the subjective differences in significance between points on the scale. A graph of the function depicts changes in the professional archaeologists' preferences that result when passing from one point on the scale to another. The function also describes the archaeologists' attitudes toward risk; a rate of change in preference different from the rate of change in the scale of significance indicates an aversion to or proclivity for the chance of moving from one point on the scale to another. While the exact shape of this preference function may be subject to mild professional/academic disputation, the opinions of the archaeologists contributing to its assessment are widely known and well supported in the archaeological literature.

The Regression. The next step in the analysis was to define the set of independent variables, i.e., those locational characteristics of sites which might be correlated with the scale of significance. This process was based partially on observations or untested hypotheses from previous cultural studies, but mainly on the experience and intuition of the participating archaeologists. The initial set of variables and the rationale for their selection is presented below:

- Soil Association. Most of the larger Anasazi habitation sites were located close to areas used for dry cultivation of corn, beans, and squash. It was felt that lands with deep, well-drained warm soils would have been attractive as settlement sites. This variable was initially measured on the land use and soils map based on U.S. Soil and Conservation Service data. A subsequently prepared map of probable prehistoric dry farming areas proved to be more specific and more reliable.

- Slope in a Cell. The more important post-archaic sites in the area were located on relatively flat ground. A number of sites were located on cliffs or canyon sides, but these are generally smaller, more recent, and were occupied for a shorter time span

Table D-5. ARCHAEOLOGICAL CONSTRAINTS MAP: SCALE OF SIGNIFICANCE

SITE DESCRIPTORS

Each site is identified by a four-digit code that describes a site's period (age), type, size, and multiple-occupation history. The legend to the four-digit code is presented below.

Period of Occupation (Age)

Phase Name	Code
Archaic	1
Anasazi	
Basketmaker II	1
Basketmaker III (La Plata)	2
Piedra (P I)	2
Ackmen (early P II)	2
Mancos (late P II)	3
McElmo (early P III)	3
Mesa Verde (late P III)	3
Post-Anasazi (Ute, Navajo, Hopi)	4
Unknown	5

Type of Site

Name	Code
Large habitation with great kiva	1
Large habitation with three or more kivas or pit houses	2
Reservoir or tower	3
Habitation with two kivas or pit houses	4
Habitation with one kiva or pit house	4
Shrine	5
Seasonal habitation (camp or field house)	5
Petroglyphs or pictographs	5
Food or lithic processing area	6
Quarry	6
Hunter's outpost	6
Terraces or check dams	6
Storage facility	6

Table D-5. (continued)

Size of Site

Area (sq. meters)	Code
5000+	1
Less than 5000	2

Multiple Occupations

Number of Times Occupied	Code
3 or 4	1
1 or 2	2
Unknown	3

SCALE

Period of Occupation	Type	Size	Multiple Occupations	Significance
1	Any	Any	-	7
Any	1	Any	-	7
2	2	1	1	6
2	3	1	1	6
2	4	1	1	6
3	2	1	1	6
3	3	1	1	6
3	4	1	1	6
2	2	2	1	5
2	3	2	1	5
2	4	2	1	5
3	2	2	1	5
3	3	2	1	5
3	4	2	1	5
2	2	1	2	4
2	3	1	2	4
2	4	1	2	4
3	2	1	2	4
3	3	1	2	4
3	4	1	2	4
2	2	2	2	4
2	3	2	2	4
2	4	2	2	4

Table D-5. (concluded)

Period of Occupation	Type	Size	Multiple Occupations	Significance
3	2	2	2	4
3	3	2	2	4
3	4	2	2	4
4	2 or 4	1	-	4
4	2 or 4	2	-	4
5	2	1	3	4
5	3	1	3	4
5	4	1	3	4
5	2	2	3	4
5	3	2	3	4
5	4	2	3	4
2	5	1	1	3
3	5	1	1	3
2	5	1	2	3
3	5	1	2	3
5	5	1	3	3
2	5	2	1	3
3	5	2	1	3
2	5	2	2	3
3	5	2	2	3
5	5	2	3	3
4	5	1	-	3
4	5	2	-	3
2	6	1	1	2
3	6	1	1	2
2	6	1	2	2
3	6	1	2	2
5	6	1	3	2
2	6	2	1	2
3	6	2	1	2
2	6	2	2	2
3	6	2	2	2
5	6	2	3	2
4	6	1	-	2
4	6	2	-	2
No site				1

than those on flatter ground, and hence are not considered to be as significant. This variable was measured as the percent slope in each cell of the well field grid.

- Drainage Rank. The Southwestern Anthropological Research Group (SARG) has developed a stream tributary ranking system, where the smaller numbers refer to larger tributaries low in the drainage. The more important sites, according to the significance scale, seemed to be located in close proximity to drainages assigned a middle ranking (usually those draining middle elevation plateaus). Drainages in the CO_2 well fields were assigned a rank from one to ten. The variable was measured as the rank of the nearest stream to a cell, with the lowest rank corresponding to the extremes of the SARG scale and the highest rank corresponding to the mid-points of the SARG scale.

- Topographic Aspect. Many sites seemed to be oriented to a southeastern exposure, where protection from harsh weather was the greatest. Aspect was initially measured in increments of 15° of arc, moving away from a southeasterly direction of 150° from north. This was later simplified to three directional categories (southeast, east and southwest, and other).

- Distance to the Dakota-Morrison Contact. The Dakota Sandstone is a pervious water-bearing massive sandstone that caps most of the plateaus in the project area. It is a cliff-forming material. The Dakota is underlain in most areas by the Morrison Formation, consisting of softer and more impervious shales, clays, and siltstones. The Morrison Formation forms slopes. The contact between the Dakota-Morrison indicates the location of rimrock, talus slopes, and the most probable location of springs or seeps. It was thought that some sites might be located close to this contact to take advantage of defensive locations, building materials, and water supply. This variable was measured in 400-ft increments from a cell.

- Elevation. More important sites were thought to be located at higher elevations in each of the well field areas. This variable was measured as the differential elevation over the lowest elevation in each well field area.

- Maximum Elevation Change Within 3200 Feet of a Cell. It was observed that many sites, particularly the more recent ones, were located near the crest of a slope or the rim of a canyon. This variable sought to measure proximity to a significant change in topographic relief. It was measured as the greatest gain or loss in feet of elevation within 3200 feet (8 cells) of a cell.

These seven variables were entered into a multiple regression; the dependent variable was site significance. The first regression run showed an extremely low correlation between the independent and dependent variables, but an extremely high correlation between several of the independent variables themselves. This suggested that several of the independent variables were measuring the same thing, and masking any correlation that might exist with the dependent variable.

Based on further discussions with the archaeologists, the set of variables was reduced to three: soil (X_1), drainage rank (X_2), and slope (X_3). These variables and their interactive terms (X_1X_2; X_1^2; $X_1X_2X_3$; etc.) were entered in linear form and as logarithmic transformations into a step-wise multiple regression. At the same time, a set of "zero" cells (where archaeological survey work had been done but no sites found) was added to the data base of known sites. By using this approach, an extremely high correlation between independent and dependent variables was attained. Separate regressions were run on each of the well fields, with different results. The Shell McElmo Dome run was based on about 1300 cases, of which 600 were zero cells. The Shell Doe Canyon run was based on 400 cases, of which about 200 were zero cells.

For the Shell McElmo Dome area, the regression equation expressing the strongest correlation between the independent (predictor) variables and the dependent variables was

$$\ln Y = X_1b_1 + X_2^2b_2 + X_3^2b_3 + X_2X_3b_4 + X_1X_2X_3b_5 + C.$$

The multiple correlation coefficient was 0.88269, with a standard error of 0.29055. The value of r^2 for this equation was 0.77914. A correlation coefficient (multiple r) of nearly 0.9 indicates an exceptionally strong "fit"; it means that about 80 percent of the variations in the data are explained by the regression relationship. The multiple r is an indicator of the predictability of this relationship. The value of r^2 indicates the percentage of variance accounted for in the dependent variable by the independent variables.

For the Doe Canyon area, the regression equation was

$$\ln Y = X_1b_1 + X_2b_2 + X_3^2b_3 + X_2X_3b_4 + X_1X_2b_5.$$

The multiple r was 0.87764, with a standard error of 0.24975. The value of r^2 in Doe Canyon was 0.77025.

The Prediction. Next, the independent variables in the regression equation were measured in each cell of the well field grids (about 100,000 cells were involved). This data matrix was then evaluated against the regression equation, solving for Y, the level of significance. This resulted in a predicted level of archaeological significance for every cell in the well field grid.

Next, a variance-covariance matrix of the regression coefficients was calculated to explain the variation in Y about its predicted value. The purpose of this step was to establish the standard deviation of Y as a function of the set of predictor variables, and hence obtain a more accurate expression of the probabilistic distribution surrounding the predicted value in each cell. This was necessary to make more effective use of the utility function (preference function) for the scale of site significance; the utility function interprets the probability distribution about a point on the scale of significance in terms of the attitude toward risk reflected in the curve.

Based on the predicted level of significance (Y) in each cell and on the variance of the value calculated in the matrix, the value of Y at 5, 50, and 95 percent levels of confidence was calculated. Then the utility of (preference for) Y at each level of confidence was calculated from the utility function. Finally, the "expected utility" (a value that considers both the predicted level of Y and its probability distribution) was computed for each cell. The expected utility is a numerical expression of the preference accorded by the archaeologists to a predicted level of significance and the uncertainty associated with that prediction. As a last step, the expected utility of each cell was transformed back into an "equivalent significance value" that corresponds to a point on the scale of significance. This equivalent value for a cell means that, considering the prediction and its uncertainty, the archaeologists would impart the same importance to that cell as to another cell containing a known site of the same significance as the equivalent value. This is to say that the equivalent significance values are comparable to the real significance of known sites.

The effect of calculating the equivalent significance value may be seen in relation to the curve of the utility function (Figure D-2). Between the values of 3 and 4 on the scale of significance, the rate of decrease in utility is much more rapid than the rate of change on the scale of significance, indicating an aversion to the risk of a prediction falling at a higher point on the scale. Because of its uncertainty (however minor), a predicted value between 3 and 4 will result in a slightly higher equivalent significance value for a given cell. Conversely, a predicted value between 5 and 6 (corresponding to a slightly risk-prone portion of the preference curve) will result in a slightly lower equivalent significance value. A more detailed description of the mathematical approach to calculating expected utilities is presented in Attachment D-1.

<u>The Constraint Maps</u>. The foregoing analytical steps resulted in a predicted level of significance and an equivalent significance value for each cell in the well field grids. Two maps were plotted for each of the well field areas, showing predicted and equivalent values, respectively. The maps were plotted in tenths of a point on the scale of significance, allowing for a fine differentiation between individual cells in the well field. The maps were then colored in several categories

of predicted or equivalent significance to show at a glance the generalized differential constraints to development associated with archaeological resources. The maps showing equivalent values were intended to be the final archaeological constraints maps, and were used for planning purposes. The predicted values maps were provided to support and explain the equivalent values maps.

Trade-Off Model. The purpose of this step was to combine the information on the environmental, geologic, and archaeological constraints maps and produce a single "composite constraints map" for each well field. This required that the importance of archaeological constraints be determined in relation to geologic and environmental constraints, so that a single constraint value incorporating the trade-offs among archaeology, geology, and environment could be calculated for each cell. The assessment of trade-offs was based on subjective judgments and was done in two steps.

First, the order of importance of the three types of constraints was established. This was accomplished by asking the planning team which type of constraint they would want to move first to its highest value if, for a given cell, all the constraints were at their worst value. Then, it was asked which of the remaining two should be moved to its highest value. This process identified archaeology as the most important constraint, followed by geology, and then environment.

The next step was to quantify the perceived differences in importance between the three types of constraints. This was done using a question-and-answer technique in which the team was presented with two hypothetical cells. One cell had the best (least constraint) value for archaeology and the worst value for geology; the second cell had the worst value for archaeology and the best for geology. The team was asked to give a value for archaeology in the first cell that would leave them indifferent to a choice between the two cells. The response to this query indicated the amount of archaeological value the team was willing to give up to move from the worst to the best value of geology. This process continued until the trade-offs among all three types of constraints had been established; a series of additional trade-off questions was posed to ensure that all responses were consistent.

The responses from these questions were used to calculate "trade-off constants" for each type of constraint. These constants indicate the relative weight of a constraint. The constant for archaeology was 0.77, for geology 0.16, and for environment 0.07.

Since a utility function had been developed for each type of constraint, it was possible to combine all three utility functions and their trade-off constants into a single composite utility function. This equation computes for each cell a single numerical value that embodies the environmental, geologic, and archaeological constraint values and their relative weights. The function is described in greater detail in Attachment D-1.

These values were then plotted as a composite constraints map, showing aggregate differential constraints to development in the well field. This map was colored in five categories of roughly equivalent composite utility. The composite constraints map is the final planning tool produced in this task, and is intended for use as the general reference for well field planning.

ARCHAEOLOGICAL DRAFT VERIFICATION

Background and Purpose

A regression model was developed for predicting archaeological significance of a given cell in the study area. The development of the regression model was based on available data from archaeological surveys in the study area and construction of a scale of archaeological significance. The regression model fitted the data quite well as was indicated by a high correlation coefficient and a low standard error. It should be noted that the model predicts archaeological significance of a cell given that it contains a archaeological site.

In order to verify the validity of any model, it is desirable to test the model against an independent data set i.e., a data set which is not used in the development of the model. It was, therefore, decided to collect additional data on archaeological significance of several cells which were not surveyed before and consequently were not a part of the data base used in developing the model. The motivation behind this exercise was that if the new data were found consistent with the predictions of the model, this would ascertain the accuracy of the model and provide the confidence to its use to predict archaeological significance of other cells in the study area. On the other hand, if the new data were completely inconsistent with the predictions of the model, modifications to the model would be clearly necessary.

The purpose of this section is to summarize the analysis conducted in the verification phase and describe the conclusions drawn from the analysis. The various steps involved in the analysis are:

- Design of an experiment for sampling
- Collection of data
- Statistical analysis of data.

Design of an Experiment for Sampling

In order to verify the validity of the model over the complete range of the scale of archaeological significance, cells from the study area were selected randomly corresponding to predicted archaeological significance values of 1 ($\pm$0.1), 2 ($\pm$0.1), 3($\pm$0.1), 4$\pm$0.1), and 5 ($\pm$0.1). The procedure used was as follows. Two random numbers were selected to identify the row and column of a cell. If the predicted significance value of the cell was within one of the ranges shown above, it was listed under that range and marked on a map. If the predicted value was outside any of the ranges, that cell was discarded and a new cell was selected. This was repreated until 20 to 40 cells were listed under each range, according to the distribution of values predicted by the model. This experimental design corresponds to a random stratification scheme in which the strata are defined by predicted significance values and cells (samples) are selected randomly within each stratum. The sample size of 20 to 40 cells within each stratum was considered adequate erstimation of the average value within $\pm$ 20 percent would be reasonable.

Collection of Data

A survey crew of 3 individuals (2 archaeology students and a professional archaeologist) visited each of the cells selected for sampling. All the factors which determine their archaeological significance were noted for each cell. This information enabled the calculation of an archaeological significance value for the cell. Out of the 140 cells surveyed, 17 were found to contain archaeological sites. Table D-6 shows the predicted and the observed archaeological significance values for the 17 cells. Since the regression model predicts the archaeological significance of a cell given that the cell contains an archaeological site, the 17 cells shown in Table D-6 are of interest in verifying the predictions of the model. Each of the sites encountered on this sampling survey were recorded on state of Colorado site survey forms; these forms were forwarded to the State Historic Preservation Officer.

Table D-6. NEW DATA COLLECTED IN THE VERIFICATION PHASE

Obs. No.	Predicted y, y_i	Observed y, y_i
1	1.1	4
2	1.9	4
3	2.0	3
4	2.0	2
5	2.9	7
6	2.9	2
7	3.0	2
8	3.0	4
9	3.0	2
10	3.0	3
11	3.0	4
12	3.9	3
13	3.9	3
14	4.1	3
15	4.1	2
16	4.9	7
17	4.9	3

Statistical Analysis of Data

Three types of analysis were conducted:

- verification of new observations based on prediction intervals
- comparison of observed values and equivalent values calculated from the model
- Kolmogorov - Smirnov test for verifying the assumed model distribution

Verification of New Observations Based on Prediction Intervals. Let y denote archaeological scale. Let y_i be the observed archaeological significance of i^{th} cell shown in Table 1 and y_i be the predicted archaeological significance for the same cell. The objective of the analysis is to construct a prediction interval for y_i at a specified confidence level, say $(1-\alpha)$ based on the model before surveying the i^{th} cell and to examine whether or not the observed value falls within the predicted interval. If the observed value does not fall within the predicted interval, it can be said with a confidence of $(1-\alpha)$ percent that the new observation does not contradict the model, or in other words the new observation seems to be consistent with the prediction of the model.

Table D-7 shows the predicted y $(\hat{y}_i)$, prediction interval for y_i at 90 percent confidence level and the observed y (y_i). It is seen that all observations except three fall within the predicted intervals. One of the observed values falling outside the predicted interval is 7 (observation number 5).

This site was an archaic period lithic scatter, located at the base of a talus slope. All archaic sites are considered to be of high significance, but archaic period activities and location choices were not modeled in the predictive approach. The predictive model focuses on the Anasazi phases. Hence the high significance value of the observation is an anomaly not accounted for by the model, and can be ignored in the verification based on predicted interval.

Table D-7. VERIFICATION OF NEW OBSERVATIONS BASED ON PREDICTION INTERVALS

Obs. No.	Prediction Y, Y_i	Predicted Interval for Y_i with 90 percent confidence level	Observed, Y_i
1	1.1	1-1.8	4*
2	1.9	1.2-3.1	4*
3	2.0	1.2-3.2	3
4	2.0	1.2-3.2	2
5	2.9	1.8-4.7	7*
6	2.9	1.8-4.7	2
7	3.0	1.9-4.8	2
8	3.0	1.9-4.8	4
9	3.0	1.9-4.8	2
10	3.0	1.9-4.8	3
11	3.0	1.9-4.8	4
12	3.9	2.4-6.3	3
13	3.9	2.4-6.3	3
14	4.1	2.5-6.6	3
15	4.1	2.5-6.6	2
16	4.9	3.0-7	7
17	4.9	3.0-7	3

*Observed level outside the predicted interval.

Comparison of Observed Values and Equivalent Values Calculated From the Model. The regression model provides a probability distribution of the archaeological significance, Y_i of a cell which is not yet surveyed. The distribution of Y_i cannot be directly compared with the single observed value of the archaeological significance for that cell after being surveyed. However, techniques of utility (preference) theory can be used to replace a probability distribution of a variable, X by a number X* which has the same expected utility as that of the distribution. The number X* is called the equivalent level of X. A utility function was previously assessed for the archaeological significance scale. Using this function and the probability distribution of Y_i, the equvialent of level of Y_i (denoted by Y_i*) was calculated. Table D-8 shows the predicted Y, equivalent Y and the observed Y for the 17 cells survey in the verification phase.

An estimate of standard error, S_e of prediction can be obtained as follows

$$S_e = \sqrt{\frac{(Y - Y_i^*)^2}{n}} \qquad (1)$$

where n = number of observations.

Using all 17 observations, S_e was calculated to be 1.58. This represents about 46 percent variability, about the average of the observed values. As was pointed out earlier, the observation number 5 for which Y_i equals 7, should not be counted. If this observation is excluded, S_e is found to be 1.34 which represents about 42 percent variability about the average of the observed values. The magnitude of the standard error of prediction calculated above is identical with the standard error of 1.34 of the regression model itself.

Table D-8. PREDICTED, EQUIVALENT AND OBSERVED LEVELS OF ARCHAEOLOGICAL SIGNIFICANCE

Obs. No.	Predicted Y, Y_i	Equivalent Y, Y_i^*	Observed Y, Y_i
1	1.1	1.67	4
2	1.9	2.37	4
3	2.0	2.50	3
4	2.0	2.50	2
5	2.9	3.3	7
6	2.9	3.3	2
7	3.0	3.35	2
8	3.0	3.35	4
9	3.0	3.35	2
10	3.0	3.35	3
11	3.0	3.35	4
12	3.9	3.88	3
13	3.9	3.88	3
14	4.1	3.99	3
15	4.1	3.99	2
16	4.9	4.36	7
17	4.9	4.36	3

Kolmogorov-Smirnov Test for Verifying the Assumed Model Distribution. In the development of the regression model, a lognormal distribution was assumed for the archaeological significance scale Y. The new observations can be used to verify the validity of this distribution. The Kolmogorov-Smirnov test is conducted by comparing the theoretical (model) distribution of Y with the observed levels of Y. We will select the model distribution which has a mean Y of 3($\pm$ 0.1), since the maximum number of new observations (7) are generated from this distribution.

Table 4 shows the observed Y for i^{th} cell, the observed cumulative distribution function (CDF), the theoretical CDF and absolute deviation between the observed CDF and the theortical CDF. The maximum deviation, d_* in Table D-9 is seen to be 0.348. Assume that a confidence level of 90 percent is desired, i.e., $1-\alpha = 0.9$. The critical value of the test statistic for $n=7$ and $\alpha = 0.1$ is found to be 0.482 from statistical tables. Since $d^* = 0.348 < 0.482$, we conclude that the new data do not contradict the assumed distribution of the model.

Conclusions

The three types of statistical analysis conducted all indicate that the new data collected after the development of the regression model do not show any significant departures from the predictions of the model. The new data are also compatible with assumed model distribution, i.e., the average of observed values and the deviations from the average of the observed values are not significantly different from what one would have expected from the probability distribution assumed for the model.

Table D-9. DATA FOR KOLMOGOROV-SMIRNOV TEST

Obs. No.	Observed Y, Y_i	Observed CDF $F^*_y(y_i)=i/n$	Theorgtical CDF $F_y(y_i)$	[F*-F]
1	2	0.14	0.082	0.058
2	2	0.29	0.082	0.21
3	2	0.43	0.082	0.348
4	3	0.57	0.50	0.07
5	4	0.71	0.839	0.13
6	4	0.86	0.839	0.02
7	7	1.0	0.999	0.001

Attachment D-1

WELL FIELD DEVELOPMENT PLAN
PROCEDURES FOR QUANTITATIVE ANALYSIS

The body of Appendix D describes in narrative form the development and use of analytical models and procedures in the prediction of archaeological significance and the preparation of constraint maps. Attachment D-1 is a more detailed listing of quantitative analytical procedures, in expository mathematical notation.

A. Environmental Constraints Map: Procedure for combining land use constraints and biologic constraints into environmental constraints.

1. Land Use. The land use scale (Z_1) is defined by four points, where 1 is the best value and 4 is the worst value.

   Calculate the utility of the land use constraints scale from:

$$U_{Z_1}(z_1) = 1 - \left(\frac{z_1 - 1}{3}\right)^2. \tag{1}$$

$$\text{e.g., } z_1 = 2; \quad U_{Z_1}(2) = 1 - \left(\frac{2 - 1}{3}\right)^2 = 0.889.$$

2. Biology. The biologic constraints scale (Z_2) is defined by three points, where a value of 1 presents the least constraints and a value of 3 is the most constraining.

   Calculate the utility of the biologic constraints scale from:

$$U_{Z_2}(z_2) = 1 - \left(\frac{z_2 - 1}{2}\right)^{1.5} . \quad (2)$$

e.g., $z_2 = 2$; $U_{Z_2}(2) = 1 - \left(\frac{2 - 1}{2}\right)^{1.5} = 0.646.$

3. Tradeoff. An additive utility function is assumed. The combined utility of biology and land use is U_Z.

$$U_Z(z_1,z_2) = C_1U_{Z_1}(z_1) + C_2U_{Z_2}(z_2).$$

a. The tradeoff assessment between biology and land use yielded that biology (C_2) was relatively more important than land use (C_1), and

$C_1 = C_2\, 0.646$; $C_1 + C_2 = 1$.

Hence $C_1 = 0.392$ and $C_2 = 0.608$.

b. Calculate the combined utility of environmental constraints from:

$$U_Z(z_1,z_2) = 0.392\ U_{Z_1}(z_1) + 0.608\ U_{Z_2}(z_2). \quad (3)$$

e.g., land use scale = 2, biology scale = 2;
combined utility $U_Z = 0.392 * 0.889 + 0.608 * 0.646 = 0.741$

B. Geologic Constraints Map: Procedure for calculating utility of the geologic constraints scale. A three-point scale is used, where a value of 1 is the least constraining and a value of 3 is the most constraining.

Calculate the utility of the geologic scale (S) from:

$$U_S(s) = 1.5 - 0.5 * s. \tag{4}$$

e.g., $s = 2$; $U_S(2) = 1.5 - 0.5(2) = 0.5$.

C. Archaeological Constraints Map: Procedures predicting archaeological significance, calculating a variance-covariance matrix of regression coefficients, calculating the expected utility of predicted values, and calculating the equivalent archaeological significance of a cell.

1. The Prediction Model. The model is expressed as:

$$E\,[\ln Y_i] = \sum_{j=0}^{10} b_j x_{ij}, \tag{5}$$

where

Y_i = archaeological significance of i^{th} cell (on a scale of 1 to 7)

X_{i0} = 1 for all i

X_{i1} = soil type of i^{th} cell

X_{i2} = (stream rank of i^{th} cell)^2

X_{i3} = (slope of i^{th} cell + 1)^2

X_{i4} = (stream rank of i^{th} cell) * (slope of i^{th} cell + 1)

X_{i5} = (soil type of i^{th} cell) * (stream rank of i^{th} cell) * (slope of i^{th} cell + 1)

and where

b_j = regression coefficients, as follows:

b_0 = 0.66492

b_1 = 0.31665

$b_2 = -0.013035$

$b_3 = -0.0031159$

$b_4 = 0.027991$

$b_5 = 0.0058726$

For obtaining better correlation, slopes greater than 21 percent were set to 21.

Check: After substituting the above b_j values, check the $E[\ln Y_i]$ value for known soil type, stream rank, and slope values for one of the control cells.

2. Calculating the Variance-Covariance Matrix of Regression Coefficients. Consider the control cells which were included in the regression analysis. Form the following matrices:

$$\underline{b} = \begin{bmatrix} b_0 \\ b_1 \\ \cdot \\ \cdot \\ \cdot \\ b_5 \end{bmatrix}$$

$$\underline{X} = \begin{bmatrix} X_{10} & X_{11} & \cdots & X_{15} \\ X_{20} & X_{21} & \cdots & X_{25} \\ \vdots & \vdots & \vdots & \vdots \\ X_{n0} & X_{n1} & \cdots & X_{n5} \end{bmatrix}$$

Note: $X_{10} = X_{20} = \ldots = X_{n0} = 1$

where n = number of control cells = 647.

The variance-covariance matrix of $\underline{b}$ is then given by:

$$V[\underline{b}] = E[\sigma^2](\underline{X}^t\underline{X})^{-1}, \qquad (6)$$

where

$$E[\sigma^2] = \text{square of the standard error} = (0.29055)^2.$$

Note: $\underline{X}$ is n x 6; $\underline{X}^t$ is 6 x n; $\underline{X}^t\underline{X}$ is 6 x 6, and $V[\underline{b}]$ is 6 x 6.

The variance of $\ln Y_i$ can be calculated from

$$S^2[\ln Y_i] = (\underline{X}_i^t) \; V[\underline{b}] \; (\underline{X}_i) + E[\sigma^2] \tag{7}$$

where

$$\underline{X}_i = \begin{bmatrix} X_{i0} \\ X_{i1} \\ \cdot \\ \cdot \\ \cdot \\ X_{i5} \end{bmatrix} \qquad \underline{\text{Note}}\ X_{io} = 1$$

Note: $\underline{X}_i$ is 6 x 1; $\underline{X}_i^t$ is 1 x 6; $V[\underline{b}]$ is 6 x 6.

3. Calculating the Expected Utility of the Predicted Significance Value in a Given Cell.

a. Calculate the expected value of $\ln Y_1$ from equation (5).

b. Calculate the variance of $\ln Y_i$ from equation (7).

c. Calculate the 5, 50, and 95 percentiles of $\ln Y_i$ from the following equations:

$$[\ln Y_i]_{0.05} = E[\ln Y_i] - 1.644 * S[\ln Y_i] \tag{8}$$

$$[\ln Y_i]_{0.50} = E[\ln Y_i] \tag{9}$$

$$[\ln Y_i]_{0.95} = E[\ln Y_i] + 1.644 * S[\ln Y_i] \tag{10}$$

d. Find the antilogs of the quantities found in equations (8) through (10) as follows:

$$[Y_i]_{0.05} = \exp\left\{[\ln Y_i]_{0.05}\right\} \qquad (11)$$

$$[Y_i]_{0.50} = \exp\left\{[\ln Y_i]_{0.50}\right\} \qquad (12)$$

$$[Y_i]_{0.95} = \exp\left\{[\ln Y_i]_{0.95}\right\} \qquad (13)$$

e. Calculate the utilities of $[Y_i]_{0.05}$, $[Y_i]_{0.50}$, and $[Y_i]_{0.95}$ from the following equations (taken from the figure in Attachment D-2):

for $1 \leq y \leq 4$,

$$U_Y(y) = 1 - 0.6\left(\frac{y-1}{3}\right)^{4.419}, \qquad (14)$$

for $4 < y \leq 7$,

$$U_Y(y) = 0.4\left\{1 - \left(\frac{y-4}{3}\right)^{0.6309}\right\}. \qquad (15)$$

Let these utilities be $U_{0.05}$, $U_{0.50}$, and $U_{0.95}$, respectively.

f. Calculate the expected utility of the given cell from:

$$E[U_i] = U_{0.50} + 0.185 * (U_{0.95} + U_{0.05} - 2U_{0.50}) \qquad (16)$$

4. Calculating Equivalent Archaeological Significance of a Given Cell. Calculate the equivalent archaeological significance $\hat{y}$ of the i^{th} cell, which has an expected utility of $E[U_i]$. Thus,

$$\hat{y}_i = 3\left\{\frac{1 - E[U_i]}{0.6}\right\}^{1/4.419} + 1,$$

$$\text{if } 0.4 \leq E[U_i] \leq 1; \qquad (17)$$

and

$$\hat{y}_i = 3 \left\{ 1 - [E(U_i)/0.4] \right\}^{1/0.6309} + 4,$$

$$\text{if } E[U_i] < 0.4. \qquad (18)$$

Checks on equations (17) and (18):

when $E[U_i] = 0.9$, $\hat{y}_i = 3$

when $E[U_i] = 0.2$, $\hat{y}_i = 6$.

D. Composite Constraints Map: Procedures for combining the archaeological, geologic, and environmental scales to calculate composite utility.

1. Attributes

Y = archaeological significance

Z = environmental constraints

S = geologic constraints

The attribute "environmental constraints" consists of two subattributes:

Z_1 = land use constraints

Z_2 = biologic constraints

2. Tradeoffs. An additive utility function was assumed.

$$U = K_Y U_Y(y) + K_Z U_Z(z) + K_S U_S(s),$$

where

$$U_Z(z) \doteq C_1 U_Z(z_1) + C_2 U_{Z_2}(z_2).$$

The tradeoff assessments yielded that archaeology was relatively more important than geology, and geology was relatively more important than environment constraints. Specifically,

$$K_S = 0.2\ K_Y$$

$$K_Z = 0.09\ K_Y$$

$$K_Y + K_S + K_Z = 1,$$

Hence

$$K_Y = 0.775,\ K_S = 0.155,\ \text{and}\ K_Z = 0.070.$$

3. Composite Utility. To combine the archaeological, environmental, and geologic constraints maps,

   a. Use the expected utility calculated for the archaeological constraints map [equation (16)].

   b. Use the utility of geologic constraints calculated by equation (4).

   c. Use the utility of environmental constraints calculated from equation (3).

   d. Calculate the composite utility of archaeological, environmental, and geologic constraints from:

$$U = 0.775\ U_Y + 0.155\ U_S + 0.070\ U_Z \tag{19}$$

The combined utility U will be a number between 0 and 1.

INTRODUCTION

Drilling for CO_2 is less hazardous than drilling for hydrocarbon gases; however, caution and correct operational procedures are required. CO_2 is an asphyxiant - a nonflammable, odorless, colorless, and tasteless gas - and is more than 1-1/2 times as dense (heavy) as air. Because of its higher density, carbon dioxide will settle to the ground and under certain atmospheric and topographic conditions can induce suffocation. CO_2 is neither toxic nor poisonous; however, it may cut off the supply of oxygen.

This contingency plan provides examples of a typical drilling program and information regarding notification and safety procedures. This example plan briefly describes well requirements and necessary considerations which promote safe drilling operations.

Special Precautions and Considerations - Drilling Operations

Rig communications will be by a two-way radio system.

For all well kicks, the respective procedures outlined in the Shell Safe Practices Manual for Drilling and Well Servicing Operation and the Mobil Drilling Foreman's Manual will be followed. All drilling contractor personnel will be instructed in well control procedures and each employee will be assigned a specific responsibility.

Blowout Prevention Equipment

The typical drilling program will indicate the approximate depth of the well, mud program, casing sizes, and setting depths.

Blowout prevention (BOP) equipment will be installed on the 9-5/8-inch casing and tested to 2000 psi under the supervision of the drilling supervisor.

A choke line will be installed with the BOP and tested simultaneously with the BOP.

BOP will again be tested to 2000 psi after being installed following running the 7-inch casing with the test being witnesssed by the drilling supervisor.

All BOP tests will be made using clear water.

The BOP will be activated (rams closed and opened) on each trip.

Drilling Fluid Control

Water-base mud will be used with necessary additives for pH, viscosity, salinity, and water loss control as specified in the drilling program.

*This item, which is included in site-specific plans, is not presented in this example plan because its contents vary with well location and drilling conditions.

Figure E(A)-1. COMMUNICATIONS DIRECTORY AND EMERGENCY TELEPHONE NUMBERS*

	Name	Title	Office Phone	Home Phone
1.	Shell Oil Company - Midland, Texas (915/684-5511)			
	J.D. Hughes	Div. Oper. Mgr.	915/684-5511, Ext. 240	915/683-5098
	C.D. Sikes	Actg. Div. Drilling Supt.	915/684-5511, Ext. 220	915/694-5425
	R.C. Cabaniss	Div. Prod. Supt.	915/684-5511, Ext. 270	915/694-0047
	W.A. Bateman	Safety & Envir. Cons. Rep.	915/684-5511, Ext. 200	915/697-1243
	G.W. Keys	Div. Oper. Engr.	915/684-5511, Ext. 260	915/682-5858
2.	Shell Oil Company - Cortez, Colorado		Rig	Midland
	J.L. Clark	Drilling Foreman	Loffland Answering Service (505/325-5001) for Radio Contact with Rig and Foreman's Car	915/694-9943
	H.H. Crim	Drilling Foreman		915/694-5680
	M.K. Main	Drilling Foreman		915/366-8318
	C.D. Sikes	Drilling Foreman		915/694-5425
	J.F. Rusnak	Drilling Foreman		915/682-5802
3.	Mobil Oil Corporation - Midland, Texas 915/684-8211			
	G.W. Barb	Division Operations Manager - West	915/684-8211	915/682-4184
	H.H. Crabb, Jr.	Division Drilling Manager - West	915/684-8211	915/682-4858
	J.W. Culvahouse	Labor/Safety Advisor	915/684-8211	915/694-6003
4.	Mobil Oil Corporation - Hobbs, New Mexico 505/393-9186			
	A.J. Alcott	District Production Superintendent	505-393/9186	
5.	Mobil Oil Corporation - Farmington, New Mexico 505/325-1958			
	K.D. Jones	Production Supervisor		
		Answering Service	505/325-1958	
		Nights and Holidays	505/325-2552	
	R.D. Brusenham	Drilling Supervisor Cortez, Colorado		303/565-2463

Name	Title	Office Phone

6. Emergency Telephone Numbers

Bob Hampton, Montezuma County Sheriff	
Montezuma County Sheriff Department	303/565-8441
Southwest Memorial Hospital - Cortez	303/565-3743
Mercy Hospital - Durango	303/247-4311
Community Hospital - Durango	303/259-1110
Ambulance Service - Durango	303/247-1230
Ambulance Service - Cortez	303/565-7777
Colorado State Patrol - Cortez	303/565-8441

7. Regulatory Agencies

Colorado State Oil and Gas Conservation Commission Denver, Colorado		303/892-3511
Jim McKee	Senior Petroleum Engineer	
Douglas U. Rogers	Director	
Colorado State Land Board Denver, Colorado		303/892-3454
Tom Britz		
Colorado Water Resources Commission Denver, Colorado		303/892-3581 303/892-3588
Ralph Stallman		
Ron Shiff		
Mel Malley		
United States Geological Survey Durango, Colorado		303/247-5144
Jerry Long	District Engineer	
Ed Schmidt	Assistant District Engineer	
	District Clerk	
Bureau of Land Management Durango, Colorado		303/247-4082 303/247-4084
Jerry Kendrick	Area Manager	
Bud Curtis	Realty Specialist	
Helen Hawkins	Geologist	

Name	Title	Office Phone	Home Office
Environmental Protection Agency Denver, Colorado			837-3895
John A. Green	Oil & Hazardous Materials Coordinator		
Occupational Safety and Health Administration Lakewood, Colorado			303/234-4471
Jerome J. Williams	Area Director		

8. Local Residents**

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*This list will be updated as necessary.

**Names and telephone numbers of all people living within one-half mile of drilling locations.

WELL: W.O. NO. ____________

LOCATION: FIELD:

OBJECTIVE: EST. ELEVATION:

EVALUATION			GEOLOGY	DRILLING			
DRLG. TIME & SAMPLES	ELEC. SURVEYS	MUD LOGGER	SIGNIFICANT FORMATIONS	WELL DEPTH	HOLE SIZE	CASING & CEMENT	MUD PROGRAM

Figure E(A)-2. DRILLING PROGNOSIS

In final plans, the BOP installation will be shown.

Figure E(A)-3. TYPICAL BOP STACK

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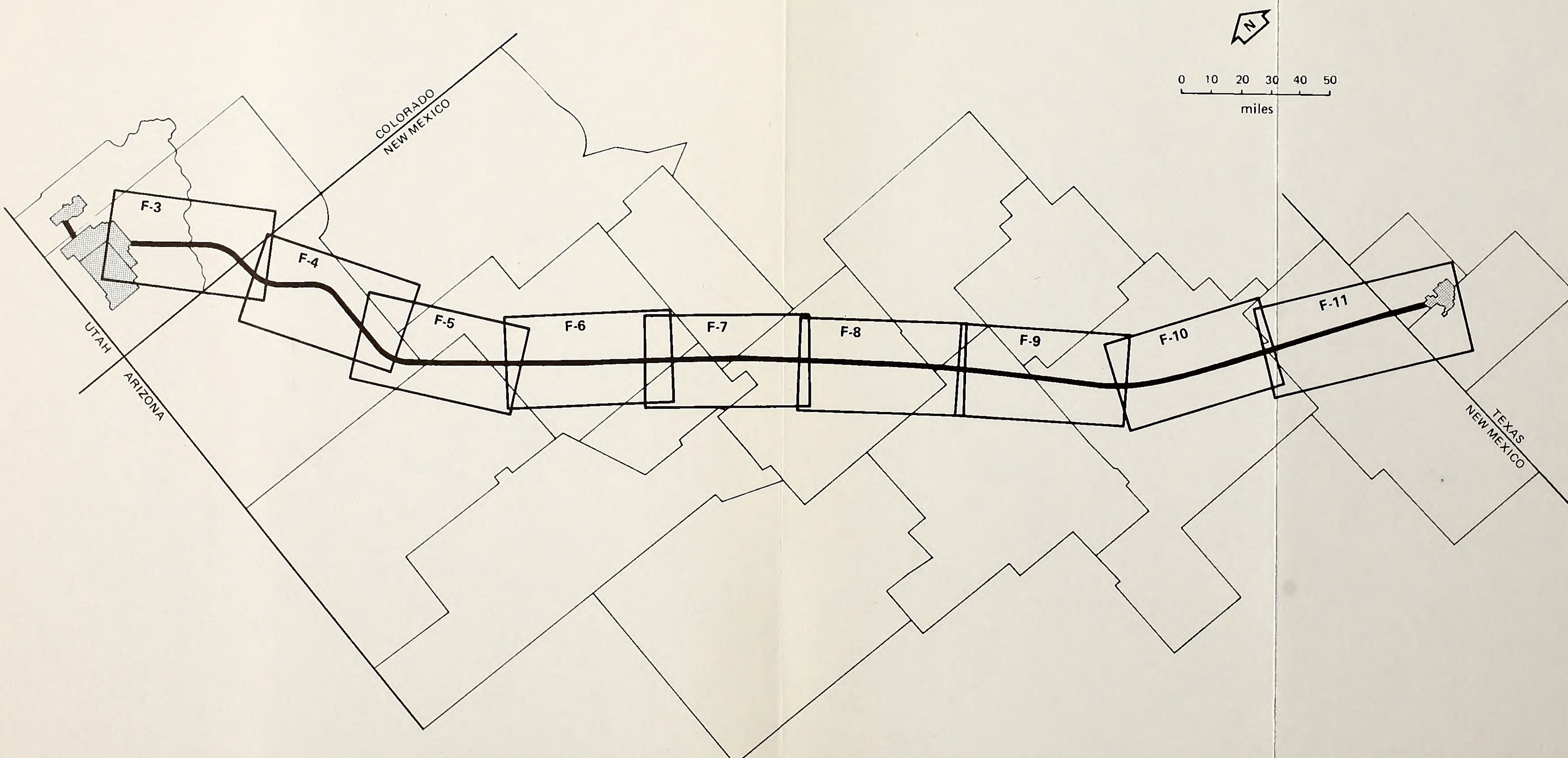


Figure F-2. INDEX MAP

LEGEND

- Not along existing right-of-way corridor
- Main CO_2 pipeline
- Mileposts
- Central facility

BLM	Public lands
STL	State lands
PRE	Private lands
USFS	National forest
Tribal name	Indian reservation or Indian trust lands

0 1 2 3 4 5
miles

- New communications tower
- Existing communications tower

Note: Tracts less than 40 acres are usually omitted because of the map scale.

Map F-3

LEGEND

Main CO_2 pipeline

Not along existing right-of-way corridor

BLM Public lands

STL State lands

PRI Private lands

Tribal name Indian reservation or Indian trust lands

1 Mileposts

E Existing communications tower

0 1 2 3 4 5
miles

Note: Tracts less than 40 acres are usually omitted because of the map scale.

Map F-4

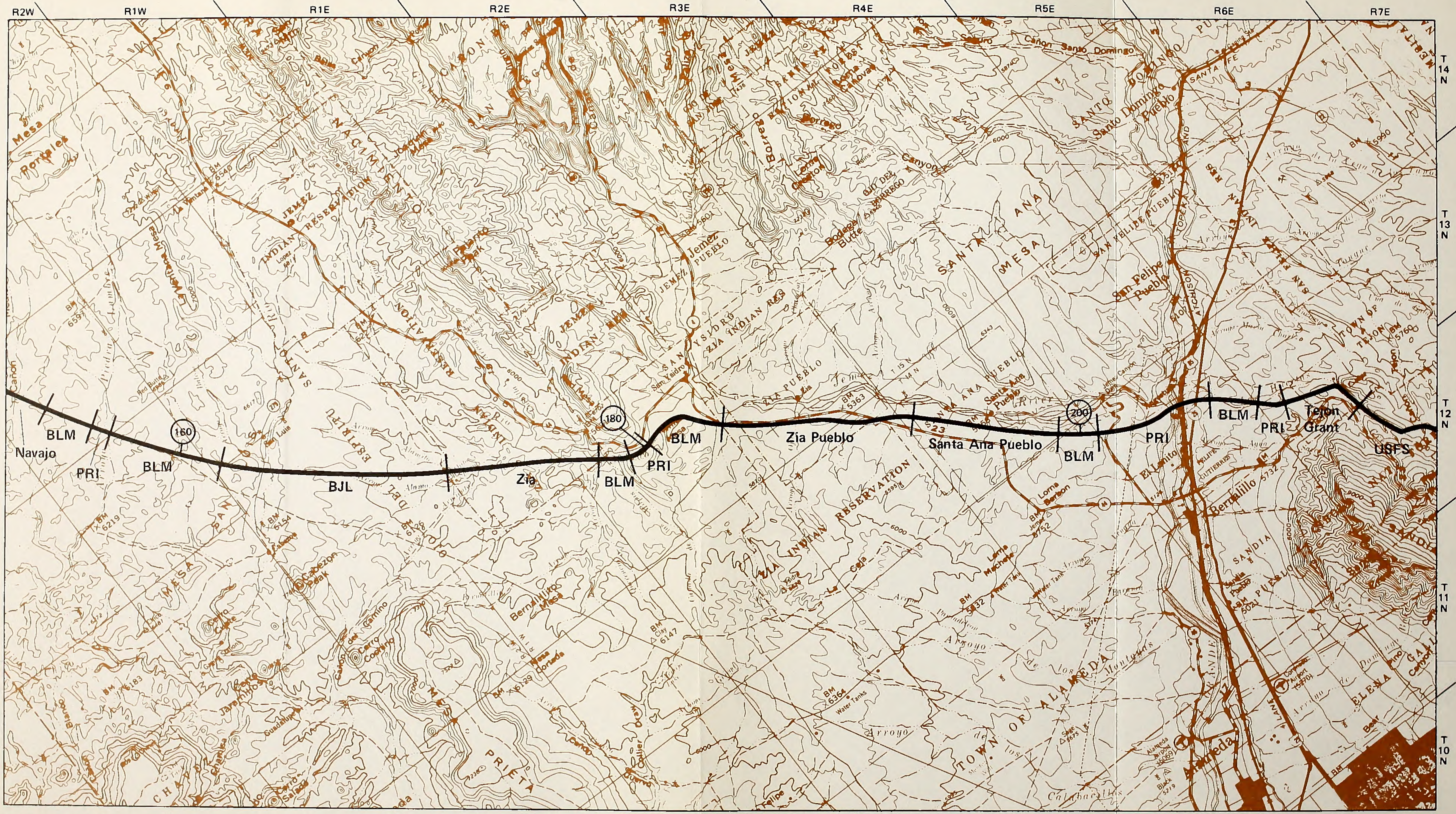
LEGEND

- Main CO_2 pipeline
- Not along existing right-of-way corridor
- C.S. Main CO_2 pipeline compressor station
- BLM Public lands
- STL State lands
- PRI Private lands
- Tribal name Indian reservation or Indian trust lands
- Mileposts
- New communications tower

0 1 2 3 4 5 miles

Note: Tracts less than 40 acres are usually omitted because of the map scale.

Map F-5



LEGEND

(pipeline line)	Main CO_2 pipeline	BLM	Public lands	USFS	National forest	Tribal name	Indian reservation or Indian trust lands
(1)	Mileposts	PRI	Private lands	BJL	Bankhead-Jones lands	Grant name	Grants

0 1 2 3 4 5
miles

Note: Tracts less than 40 acres are usually omitted because of the map scale.

Map F-6

LEGEND

(line symbol)	Main CO_2 pipeline	BLM	Public lands	USFS	National forest
(1)	Mileposts	STL	State lands	Grant name	Grants
		PRI	Private lands		

(E) Existing communications tower

0 1 2 3 4 5
miles

Note: Tracts less than 40 acres are usually omitted because of the map scale.

Map F-7

LEGEND

Main CO_2 pipeline

Mileposts

BLM Public lands

STL State lands

PRI Private lands

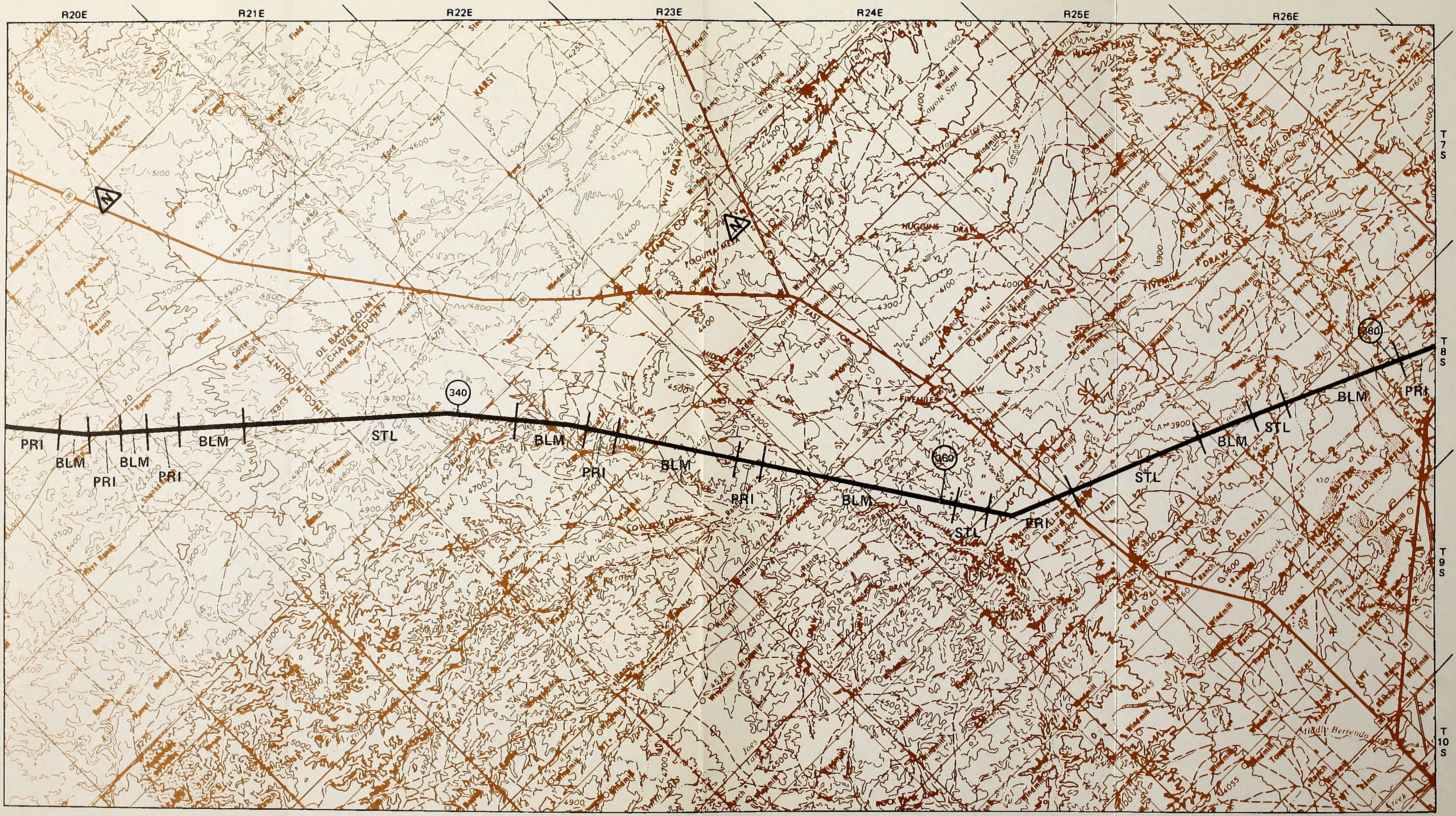
New communications tower

0 1 2 3 4 5

miles

Note: Tracts less than 40 acres are usually omitted because of the map scale.

Map F-8



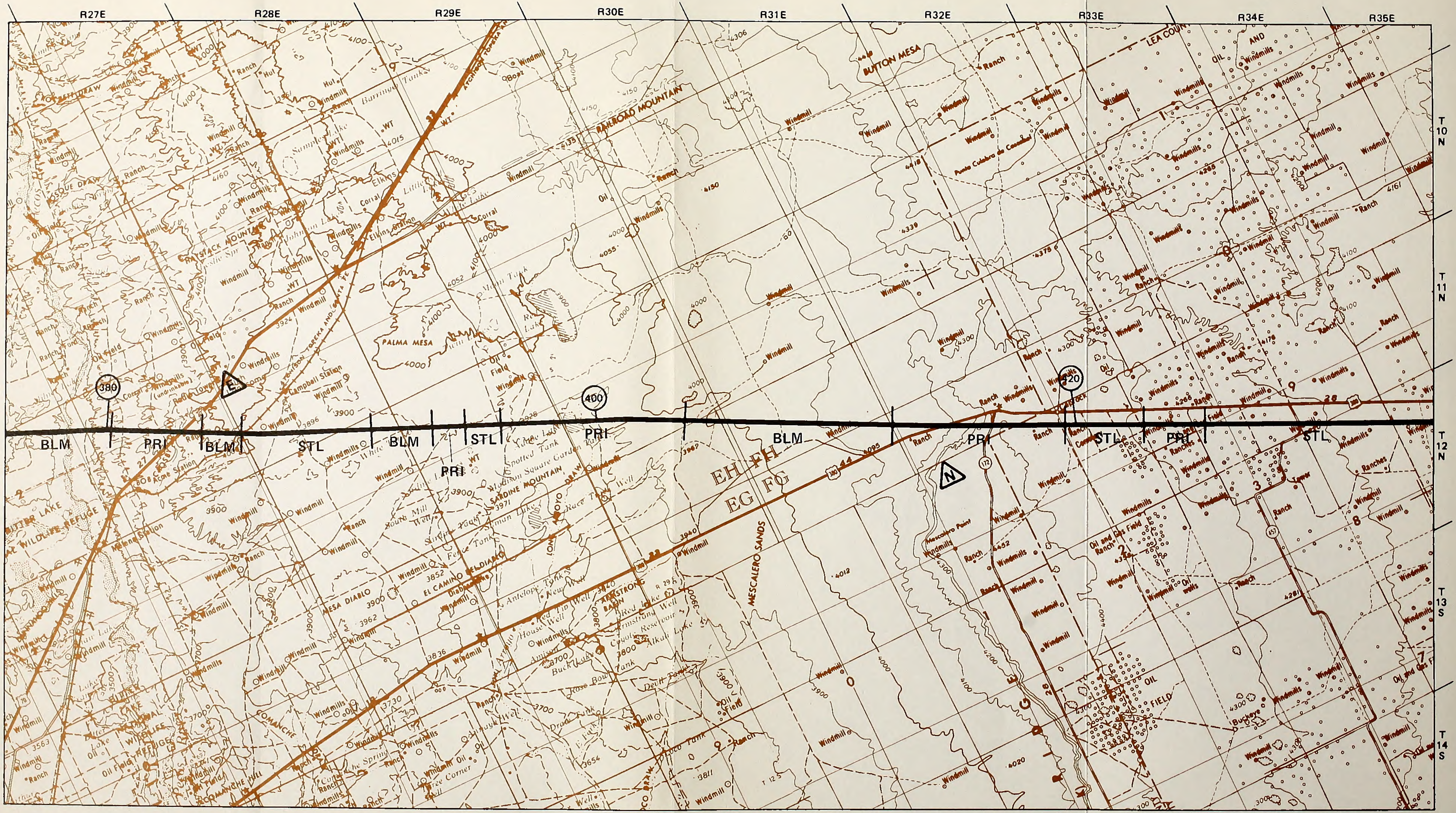
LEGEND

Main CO_2 pipeline	BLM Public lands	New communications tower	
Mileposts	STL State lands		
	PRI Private lands		

0 1 2 3 4 5
miles

Note: Tracts less than 40 acres are usually omitted because of the map scale.

Map F-9



LEGEND

Main CO_2 pipeline	BLM Public lands	(N) New communications tower
(1) Mileposts	STL State lands	(E) Existing communications tower
	PRI Private lands	

Note: Tracts less then 40 acres are usually omitted because of the map scale.

0 1 2 3 4 5
miles

Map F-10

DOE CANYON FIELD
DOE CANYON EAST CENTRAL FACILITY
DOE CANYON WEST CENTRAL FACILITY
COW CANYON CENTRAL FACILITY
HOVENWEEP CENTRAL FACILITY
R20W
R19W
R18W
R17W
R16W
R15W
R14W

Map F-1. PROPOSED CO_2 WELL FIELD FACILITIES

LEGEND

LAND OWNERSHIP

- BLM Lands
- State Lands
- National Forests
- National Parks and Monuments
- Protective Withdrawals
- Ute Mountain Lands or Reservations

SYMBOLS

- Existing Road
- Proposed Road
- Wet–CO_2 Line
- Dry–CO_2 Line
- CO_2 Well
- Central Facility and Substation
- Switching Station
- Substation only
- Proposed Electric Transmission Line (115 kV)
- Main CO_2 Pipeline
- CO_2 Well Field Study Area Boundary

N

0 1 2 3
miles

NOTE:
Symbols are for schematic purposes only; refer to text for size of specific proposed facilities.

NOTE TO MAP USERS:
Tracts less than 40 acres are usually omitted because of the map scale. Access through private lands may be restricted. The official land records in the respective offices of the Bureau of Land Management or other responsible Federal agencies should be checked for up-to-date status on any specific tract of land. Inadequacies in the BLM maps should be reported to the respective Bureau of Land Management offices from which the maps were obtained.

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Map F-12. ALTERNATE DRY-CO_2 GATHERING LINES

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LEGEND

- Proposed Transmission Corridor
- Alternate Transmission Corridor 1
- Alternate Transmission Corridor 2
- Alternate Transmission Corridor 3
- Proposed Access Road
- Alternate Access Road 1
- Alternate Access Road 2

N

0 1 2
miles

Map F-13. ALTERNATE ELECTRIC TRANSMISSION LINE AND ACCESS ROAD ROUTES FOR THE DOE CANYON FIELD

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